U.S. Office of Naval Research, London
Vol 40 No. 9/September 198

European Science Notes

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A170 780

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) 40-9	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION US Office of Naval Research Branch Office, London 6b. OFFICE SYMBOL (If applicable) ONRL	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Box 39 FPO, NY 09510	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO

11. TITLE (Include Security Classification)

European Science Notes--(UNCLASSIFIED)

12. PERSONAL AUTHOR(S)
C.J. Fox, Editor

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Monthly	FROM _____ TO _____	September 1986	29

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

European Science Notes (ESN) is a monthly publication with brief articles on recent developments in European scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the US Army Research, Development and Standardization Group. Qualified US scientists travelling in Europe may also be invited to write an ESN article.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL C.J. Fox	22b. TELEPHONE (Include Area Code) (44-1) 409-4340 22c. OFFICE SYMBOL 11

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

European Science Notes

US Office of Naval Research, London

Commanding Officer ..... CAPT T.J. McCloskey, USN
Scientific Director ..... David L. Venezky
Editor ..... C.J. Fox

September 1986
Volume 40
Number 9

Biological Sciences

This conference highlighted the potential of various types of biosensors for applications in medicine, industrial processes, and defense. Biosensor R&D is progressing rapidly, and several types of biosensors should be marketable within 3 to 5 years.

Computer Sciences

This article summarizes the work on parallel computing, artificial intelligence language research, and attribute grammars for constructing complier- and translator-writing systems being conducted at the new Departmental Unit of Computer Science at the University of Bordeaux.

The transputer is a programable computer on a chip which can be used as a single chip processor or as a component in a network forming a high-performance concurrent system. Its flexibility and compactness make it a useful building block for larger parallel systems.

The purpose of this conference, sponsored by the NATO Panel on Sensory Systems for Robotic Control, was to assess the suitability of pyramidal computer systems for major processing and computer vision. This article summarizes seven key presentations.

Mechanics

This article focuses on the research of DFVLR's Institutes for theoretical Fluid Mechanics and Experimental Fluid Mechanics and discusses, in particular, the institutes' work in the laminar wing project and separated flows and their unique wind tunnel facilities.

Physics

This article reviews some highlights of the 17th National Atomic and Molecular Physics Conference of the UK. Three of the invited contributions were by foreign experts, eight more by leading UK scientists. There were also 73 contributed presentations. The topics varied considerably, but collision phenomena predominated strongly.

The Laboratory for the Study of Microelectronic Materials at the University of Bordeaux concentrates on the preparation and careful study of thin films on semiconductor materials. Insulating films and photoelectrochemical cells are the main research lines. This article highlights the work done in the area of solid-solution fluoride thin films.

News and Notes

* * *

* * *

ESN Invites Letters to the Editor

ESN publishes selected letters related to developments and policy in science and technology in Europe and the Middle East or to interactions between the US and Europe and the Middle East in science and technology.

Letters intended for publication should be limited to 250 words and should include the writer's name, address, and daytime telephone number. Send your contributions to:

The Editor
ESN
Office of Naval Research Branch Office
Box 39
FPO, NY 09510-0700

Not all letters can be used; letters may be edited for reasons of space and clarity.

* * *

Subscriptions: *ESN* is distributed free to members and close associates of the US Government's R&D community. Others may take advantage of our subscription service: 12 issues, domestic subscriber, $27; 12 issues, foreign subscriber, $33.75; single issue, domestic, $2.25; single issue, foreign, $2.81. For a paid subscription, write to: Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

European Science Notes is a Class I Periodical prepared and distributed by the Office of Naval Research, London, in accordance with NAVSO P-35.

Biological Sciences

BIOTECHNOLOGY CONFERENCE ON BIOSENSORS SPONSORED BY THE ROYAL SOCIETY, LONDON, UK

by Claire E. Zomzely-Neurath. Dr. Zomzely-Neurath is the Liaison Scientist for Biochemistry, Neurosciences, and Molecular Biology in Europe and the Middle East for the Office of Naval Research's London Branch Office. She is on leave until July 1987 from her position as Director of Research, the Queen's Medical Center, Honolulu, Hawaii, and Professor of Biochemistry, University of Hawaii School of Medicine.

Introduction

The conference on biosensors took place at the headquarters building of The Royal Society on 28 and 29 May 1986. The large attendance attested to the great interest of scientists in biosensors for biotechnology research and development. There were about 300 participants, of whom 114 represented industrial organizations. In addition, there were representatives from government policy departments and biotechnology journals. Although the UK accounted for most of the attendees, there were also scientists from France, The Netherlands, Sweden, Switzerland, Denmark, Italy, West Germany, Norway, Canada, Israel, and Japan.

There were 15 invited speakers presenting talks on various topics in the area of biosensors, including microelectronic chemical sensors, semiconductor biosensors, electron-transfer biosensors, enzyme electrodes, immunosensors, and optical biosensors. The program topics are shown in Table 1.

It was evident from the presentations that biosensors will have a major effect on analytical science and will become important in agriculture, industry, medicine, and defense. The subject offers exciting opportunities for the application of many scientific skills to a new technology and for commercialization. The current challenges include development of methods for microfabrication of stable devices and acquisition of biological elements with appropriate properties such as thermal and temporal stability. Success requires skills ranging from semiconductor technology to protein engineering.

A summary of the presentations on this relatively new area of biotechnology research with exciting potential applications is presented in the following section.

Biosensors: Applications and Opportunities

A biosensor is a device, probe, or electrode which, when it makes contact with an appropriate sample, converts the presence of the desired analyte into an electrical signal. The biosensor is normally constructed by immobilizing a biologically sensitive material in intimate contact with a suitable transducing system to convert the concentration of the analyte into a quantifiable and processible electrical signal.

In his presentation C.R. Lowe (Biotechnology Center, Cambridge, UK) pointed out that the use of biosensors can compete with costly capital-intensive machines such as mass spectrometers, gas chromatographs, and nuclear magnetic resonance spectrometers (NMR). An important potential application in the health area is the use of biosensors for tests which can be carried out in physicians' offices, at patients' bedsides, in critical care units, etc. rather than in large central laboratories as is the situation at present. Some of the applications of biosensors mentioned by Lowe are: replacement of existing bioassays; monitoring of water pollutants; remote sensing in adverse environments (e.g., for mine gases); monitoring fermentations and cell and plant cultures; and monitoring toxic and nerve gases (military application). Biosensors can be used to measure the concentration of ions such as Mg^{2+}, K^{+}, H^{+}, and Ca^{2+} and gases, including respiratory gases such as carbon dioxide and oxygen as well as ammonia, chlorine, hydrogen sulfide, methane, etc. Clinical use includes measurement of drugs, hormones, and metabolites such as glucose

Table 1

Scientific Program
Conference on Biosensors

1. Biosensors: fundamental principles
2. Biosensors: applications and opportunities
3. Modification of microelectrode arrays: new microelectrochemical devices for sensor applications
4. Ion-selective field effect transistors (ISFETs)
5. Semiconductor biosensors
6. Biochemically sensitized field effect transistors
7. Enzyme electrodes and their application
8. Electron transfer biosensors
9. Amperometric enzyme electrodes
10. Oxidoreductase electrochemistry
11. Immunosensors
12. Amperometric immunosensors
13. Optical biosensors for immunosssays
14. Biosensors in process control
15. Microelectrodes in medicine

and urea. One great advantage of biosensor systems is that they permit the measurement of biological substances present at very low concentrations, even in the fentamole range (10^{-18}M).

Lowe listed the following advantages of biosensors: availability for a wide range of analyses, sensitive and selective, rapid response, continuous real-time assay, low cost, disposable, reagentless, operate in optically opaque and turbid solutions, computer compatible, and operator insensitive.

In another excellent presentation, I.J. Higgins (Biotechnology Center, Cranfield Institute of Technology and Leicester Biocenter, Leicester University, UK) pointed out that research on biosensors is interdisciplinary in that it involves microbiology, enzymology, electronics, immunology, physiology, recombinant DNA, and also protein engineering. Biosensors are already available commercially mostly as components of complex analytical devices. However, Higgins stated that second-generation, simpler devices, based on more sophisticated science will soon be available for medical use. This has stimulated research and development aimed at biosensors for other applications, including fermentation and process control, food testing, and environmental monitoring. Higgins projected a future world market for biosensors in the range of $20 billion. This very large market potential for sales of biosensors obviously accounted for the high proportion of attendees at the conference from industrial organizations.

Modification of Microelectrode Arrays

M.S. Wrighton (Department of Chemistry, Massachusetts Institute of Technology, Cambridge) spoke about an important aspect of biosensors, namely microfabrication, which is the interfacing of molecular systems with electronics. This work involves the contributions of electrical engineers as well as chemists. Arrays of microelectrodes can be fabricated with conventional microfabrication techniques used in the manufacture of integrated circuits. Microelectrodes of electrochemically inert materials such as gold and platinum can be modified with molecular materials in a way that leads to useful functions. Wrightman pointed out that microelectrochemical devices having diodelike and transitorlike functions can be prepared by modification of closely spaced (about one micron) microelectrodes with one or more conventional or conducting redox polymers. For the transitor function, a crucial feature is that the polymer must have potential dependent conductivity; for the diode function, the crucial feature is that adjacent microelectrodes must be coated with different redox polymers that make a connection such that charge transport from one microelectrode to the other involves a cross-redox reaction between the two dissimilar polymers. Sensor applications stem from both diodes and transitors. Wrightman and his group are working with poly(3-methylthiophene)-based transitors.

Ion-Selective Field Effect Transistors (ISFET's)

A.K. Covington (Department of Physical Chemistry, University of Newcastle Upon Tyne, UK) spoke about ion-selective biosensors. In this type of sensor, a membrane separates the inner and outer solutions, and an inner and an outer electrode is required. The membrane is responsive to ions being measured. This type of biosensor is being used in studies at Newcastle on *ex vivo* monitoring of patients' blood for potassium, calcium, and hydrogen ions during surgery. This represents a very interesting and potentially important use for ion-selective biosensors. Covington pointed out the following advantages for this use of biosensors: they are noninvasive, provide continuous monitoring and continuous calibration, do not require sterilization, and can be arrayed serially.

Most microelectronic chemical sensors are based on the field effect transistor (FET) structures; that is, on the insulated gate field effect transistor (IGFET), where the insulator-semiconductor is silicon dioxide-silicon overlain by the ion-blocker, silicon nitride, and an additional layer conferring ion sensitivity and selectivity. The metal gate connection of the FET structures is replaced by a reference electrode in the solution containing the ion to be determined (analyte). Materials used to confer ion sensitivity include, besides silicon nitride (H^+), aluminum and tantalum oxides (H^+), special glasses (H^+, Na^+, K^+), valinomycin (K^+), tetra-alkylammonium salts (Cl^-, NO_3^-) and various synthetic ionophores (Ca^{2+}, Na^+).

The use of ISFET's as biosensors in medical procedures is still in the experimental stage. However, Covington mentioned several types of application for their biosensors which are currently under investigation. These are: monitoring K^+, pH, Ca^{2+}, etc. during cardiac bypass operations; online blood analysis for liver tumor resection; monitoring Ca^{2+} during liver transplantation; ion analysis during renal dialysis. The exciting aspect of this use of ion-selective biosensors is that a continuous monitoring is possible for the concentration of ions that are critical during the

course of the above procedures so that corrective measures can be carried out to protect the patient. Some of the unsolved problems of ISFET's which still have to be resolved are: automatic encapsulation and automatic membrane deposits, vulnerability to static electricity, and drift due to unknown origins.

Semiconductor Biosensors

I. Lundström (Laboratory of Applied Physics, Linköping Institute of Technology, Sweden) discussed biosensors based on the combination of enzymatic reactions with gas-sensitive semiconductor devices and, more specifically, on ammonia-sensitive iridium-gate metal oxide semiconductor (MOS) structures and their use to measure substances like urea, creatinine, and some amino acids. This type of biosensor is extremely sensitive and can detect 0.025 μM concentrations of ammonium ions. The ammonia sensitivity is due to the absorption and catalytic properties of the thin iridium layer of the order of 3 nm thick. The gas sensor is applied behind a gas-permeable membrane and is, therefore, isolated from the aqueous surroundings. The sensor is kept at a temperature slightly above room temperature to avoid water condensation on its surface. There are two different ways to use the gas sensor: in a flow-through system and as a bioprobe.

Lundström pointed out that many biochemical reactions produce ammonia so that a sensor that detects ammonia has a wide application. One can measure free ammonium ions in air, water, and blood with applications, therefore, for use in industry, agriculture, and medicine (urea, creatinine, amino acids).

Enzyme Electrodes and Their Application

F.W. Scheller (Central Institute for Molecular Biology, Academy of Sciences, East Berlin, East Germany) presented his work on enzyme electrodes. He and his group have been able to develop enzyme-based biosensors with wide applications and high sensitivity which apparently are being marketed commercially in East Germany.

The simple instrumentation and operation of amperometric electrodes offers the opportunity to substitute them for optical devices in the clinical laboratory. Scheller et al., starting from enzyme-electrode-based analyzers for glucose, uric acid, and lactate, have succeeded in the development and application of amperometric sensors for the determination of alanine aminopeptidase and leucine aminopeptidase. Furthermore, according to Scheller, an amperometric urea electrode has been tested in monitoring the dialysis treatment of kidney patients.

Scheller et al. have also been able to obtain the highly sensitive determination of pyruvate in the micromolar range by using a lactate monoxygenase-lactate dehydrogenase (LDH) electrode which has opened up the way to the measurement of pyruvate-forming enzymes such as LDH, pyruvate kinase, and glutamate pyruvate transaminase (GPT). Nanomolar substrate concentrations (lactate or glutamate) have also been measured by self-amplifying lactate oxidase-LDH or GPT-glutamate dehydrogenese electrodes, thus almost reaching the sensitivity of biological receptors. Scheller's results showed that it is possible to mimic the behavior of biological receptors by coupled reactions with reusable immobilized enzymes. Scheller did not give specific details about his biosensor systems even though many of the participants tried to obtain more specific information during the discussion period. However, since Scheller has arrangements with industry for the commercialization of his biosensors, it is not surprising that he hedged on the details.

Immunosensors

M. Aizawa (Department of Bioengineering, University of Tokyo, Japan) discussed another type of biosensor, the immunosensor. The enzyme sensors such as those described by F.W. Scheller are applicable only for small substrates. For the measurement of macromolecules, such as large proteins, immunochemical recognition is required. The specificity of an immunosensor depends on immunochemical affinity of an antigen (e.g., protein) to the corresponding antibody. These sensors consist of solid matrix- (membrane and electrode) bound antigen (or antibody); thus the antigen-antibody complex formation on the matrix is followed by measuring membrane (or electrode) potential. Such a potentiometric immunosensor ultimately provides high selectivity in the measurement of macromolecules such as proteins.

Aizawa has developed an amperometric immunosensor for the trace analysis of specific serum components. This sensor is based on the principle of enzyme immunoassay which is dependent on the immunochemical affinity for selectivity and on the chemical amplification of an enzyme for sensitivity. Alpha fetoprotein (serum cancer marker) for instance, can be determined in the range 10^{-11} to 10^{-8} g ml^{-1} with the amperometric immunosensor. Two other applications of biomedical importance are the determination of syphilis antibody in human sera, and blood typing (blood groups A and B). The immunosensors can also be used to determine toxins present in grain for which

there is no other method as exact and simple as the use of the immunosensor. Lymphocytes can also be detected. For example, Protein A is immobilized to the membrane and binds the lymphocyte T-cells with the amperometric immunosensor, permitting determination of the concentration of T-cells. Another application is in the measurement of insulin and thyroxin levels.

Besides its high sensitivity, another important advantage of the amperometric immunosensor is that only minute amounts of antibody are required. Aizawa et al. have recently developed an optical immunosensor in which the concentration of the desired macromolecule is determined by difference of electrochemical luminescence. However, this type of sensor is still not sufficiently sensitive, and work is in progress to enhance the sensitivity.

M.J. Green (Genetics International Inc., Abingdon, UK) reviewed the principles of amperometric immunosensors. Her laboratory group is investigating immunoassays using antigens labelled with electroactive species such as ferrocine derivatives. These assays appear to be effective for monitoring therapeutic drugs such as digitoxin. However, conditions still have to be worked out for use of these amperometric immunosensors when using whole blood samples. It is also necessary to have reversible immunosensors, otherwise the method is expensive and cannot compete at present with radioimmunoassays for monitoring of drug levels in patients.

Optical Biosensors for Immunoassays

I.A. Shanks (Unilever Research, Colworth Laboratory, Bedford, UK) spoke about the potential application of optical immunosensors in the medical field and also presented some of his data on a new type of disposable sensor developed in his laboratory.

Quantitative biochemical analysis with optical sensors that incorporate antibody molecules is becoming of interest in a wide range of applications which span medicine, industrial processes, and defense. Research into optical immunosensors is still at an early stage, but such devices appear to be able to eventually replace the large, slow, costly, and complicated analyzers that currently exist. They offer advantages in size, cost, simplicity, and speed over existing analyzers while substantially retaining the sensitivity and specificity which make such immunological methods of analysis attractive.

A disposable optical biosensor which is simple and inexpensive has been developed by Shanks and his group at Unilever. Thus, the need to make a sensor that can be reused in order to cut costs is unnecessary. Shank's biosensor consists of two glass plates separated by a 100 micron gap. The whole cell fills by capillary action when a drop of the analyte is placed next to the plate. The bottom cellplate contains an immobilized layer of specific antibody. The top plate is coated with fluorescently labelled antigen. This is a competition assay between the fluorescently labelled antigen and the molecules in the analyte and antibody. The biosensor is termed a fluorescence capillary fill device. It can be plugged into a simple optical-sensor instrument; the only preliminary treatment is filtration of the analyte to remove blood cells, as the projected use is in measurement of components in blood. The method does not require a skilled technician. Only 2 minutes are required for binding of low molecular weight species and 5 minutes for high molecular weight components; only 10 to 15 minutes are required to reach equilibrium.

Shanks did not give details about, for example, dilution of antibody used because the device has been submitted for a patent application. He stated that there are still some minor problems to be worked out. However, his simple and inexpensive fluorescence capillary fill device looks very promising and should have a large potential market because it can be used in hospitals, doctor's offices, health centers, etc. without requiring a skilled technician to perform the assays.

Microelectrodes in Medicine

I.A. Silver (Department of Pathology, University of Bristol, UK) presented an interesting talk on the use of microelectrodes as biosensors for use in medicine. In this type of usage, the electrodes are placed within certain areas in the patient; i.e., *in vivo*. This contrasts with the biosensors described in the previous section in which blood is taken from the patient and then analyzed (*in vitro* assay). The membranes are bound to the microelectrodes and enzymes adsorbed onto the membranes (e.g., glucose oxidase). With the microelectrodes, it is possible to measure local blood flow, oxygen levels, glucose, etc. in a particular region of the body. The microelectrode can also be used to evaluate the extent of, for example, osteoarthritis. In this situation, osteoclasts which destroy bone attach to the bone, and a drop in pH occurs. This can be readily measured with the microelectrodes. It is also possible, according to Silver, to determine what compounds are effective in wound healing. In preliminary studies

Silver has found that it is possible to detect early stages of the presence of therosclerotic plaques with the use of microelectrodes, and for monitoring possible hazardous changes during brain surgery.

Conclusion

The meeting on Biosensors sponsored by The Royal Society highlighted the present status and future potential of various types of biosensors for application in medicine, industrial processes, and defense. Research and development of biosensors is progressing rapidly, and it is anticipated that several types will be marketable within 3 to 5 years. The specific applications are numerous, and many possibilities have been mentioned in this article. One interesting aspect of research in this area is that it has involved an interdisciplinary effort utilizing the expertise of microbiologists, engineers, immunologists, enzymologists, physicians, etc.

6/20/86

Computer Sciences

ADVANCED COMPUTING THEORY AND ARTIFICIAL INTELLIGENCE TOOLS RESEARCH AT BORDEAUX

by Paul Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1987.

The newly formed Departmental Unit of Computer Science, within the Institute of Mathematics and Information Sciences at the University of Bordeaux, France, is a rapidly growing center for fundamental research. The team was founded in 1972 by Professor R. Cori, who now heads a group of 30 scientists, 10 of whom joined the team only within the past 16 months. It is significant that Cori is not only head of this particular department, but he is also the director of GRECO #36 of the Centre National de la Recherches Scientifique (CNRS), the state-funded research authority. ("GRECO" is short for Groupement de Recherches Coordonnées, and #36 identifies the section for Advanced Programing and Artificial Intelligence [AI] Tools.)

GRECO #36--The Primary Funding Source

Before describing some highlights of the research done specifically at Bordeaux, I will briefly summarize the activities of GRECO #36, especially since the Bordeaux departmental group is one of the "Associates of GRECO," implying that, even though the department receives its basic funding from the university, a substantial fraction of its research budget comes through CNRS, and thus CNRS determines much of the activities.

GRECO #36 is made up of 25 research teams (only some of them have the status of associates), and the CNRS funds for this coordinating effort (FF6 million--about $880,000 per year) originate from the Ministry of Research. Currently there are six thematic foci:

1. Logic programing and its foundations in mathematical logic
2. Compiling theory
3. Programing environments, including program specification and program transformations, with an eye on fully automatic programing
4. Languages for AI (Prolog; Lisp; Loglisp; and, to some extent, object-oriented languages)
5. Computer architectures for AI
6. "Old fashioned" algorithm analysis and time-efficiency studies, using "modern" approaches, such as graph theory.

I have the current Scientific Report of GRECO #36, a detailed brochure which I will be glad to copy for interested parties. It is in French.

The Bordeaux Research

The University of Bordeaux department is involved, primarily, in activities related to items 1, 2, 4, and 5, above. Correspondingly, the following topics have been researched in the recent past or are to be emphasized in the near future:

- Reformulation of classical formal logic
- Graph theory
- Prolog and its combination with Lisp (Loglisp)
- Protocoll communication methods
- Computer graphics theory
- Parallel computing for AI

My first comment regards work on parallel computing. In Cori's view, this can be successfully attacked only if it is looked upon as a deeply conceived, interdisciplinary effort between hardware developers and programing scientists. In this vein, there is now a project going on in cooperation with a microelectronics

group in the engineering faculty, who not only devise circuitry but work on conceptual design as well. Incidentally, the currently favored architecture at Bordeaux is the pyramidal design, with four branches at each level.

Next, a few words about the AI language research at Bordeaux. To start with, Cori's viewpoint is that at this stage both Lisp and Prolog are indispensable and that each language has a specific field of domain where it not only outperforms the other but for which, actually, it is "the" proper language. I was pleased to hear this balanced assessment, which contrasts with the quite often expressed extremely partisan views one hears in favor of either Lisp or Prolog. Now, the most interesting AI language research currently pursued in the department is an attempt to combine Lisp and Prolog into a higher level language, appropriately termed Log!isp. The motivation for this work was a more basic task: to find an efficient way to deal with infinite systems. The researchers found that this aim can be reached precisely by a Lisp-like functional language in which Prolog (or Prolog states) can figure as functional arguments.

Finally, I will comment on work in the area of theory of computation, more specifically, a research that is directed toward the goal of devising compilers which themselves can write new compilers. This project is pursued by Dr. G. Filé, and is based on his previous experience in developments on context-free grammar. Filé's approach can be characterized by saying that he replaces states by a list of states, and thereby represents grammar by a tree. (The apex of the tree is the program; the "baseline"--the base where the tree ends--is the sequence of commands.) Nodes in the tree are given attributes, which can be considered as numerical characteristics of the program's syntax. The main problem is the efficient evaluation of the attributes, which is done in a recursive way. In particular, Filé proved that, for the efficient determination of attributes, sweeps are more powerful than passes, and visits are more powerful than sweeps. (The terms "sweep," "pass," and "visit" are standard terminology in the theory of attribute grammars and refer to the hierarchy by which the attributes to the nodes are assigned.)

While attribute grammars have been used frequently to construct compiler writing systems, until recently no applications toward constructing translators (and translator writing systems) were known. Filé's current work concentrates on this issue. In a yet unpublished manuscript ("Classical and Incremental Evaluators for Attribute Grammars" [a copy may be obtained from me]) he derived a theorem that gives the criterion for deciding if an attribute grammar is an absolutely noncircular attribute grammar. (For the definition of an absolutely noncircular attribute grammar, see, for example, H.R. Nielson, *Acta Informatica*, 19 [1983], 255-768.) Other subtypes of attribute grammars are also analyzed in Filé's preprint. The work ends with a list of unsolved problems, to be attacked at Bordeaux in the near future.

5/23/86

THE TRANSPUTER AND THE LANGUAGE OCCAM

by J.F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for industrial assessment in computer science and telecommunications.

Introduction

Some years ago Dr. Iann Barron, one of the founders of Inmos Ltd., UK, foresaw the coming need for building blocks for highly parallel computing systems as the way to achieve performance beyond that which could be achieved by advances in circuit technology. He also recognized that many individual processes within a complex operational system proceed in parallel, sometimes in a semiautonomous fashion. He realized that distributed computing within a large computing system would be advantageous in working with such operational systems. His response to this need was the design of a programable computer on a chip which could be used as a single chip processor or as a component in a network forming a high-performance concurrent system. This chip, containing processor, memory, and communication links, was called a transputer. Along with the development of the transputer came the development of a new programing language, called Occam, which is based on the same concepts of concurrency and communication inherent in the transputer. (*ESN* 40-4:142 [1986] and *ESN* 39-9: 443 [1985]).

Transputer Architecture

The architecture of the transputer obtains the maximum of functionality on a minimum-sized chip. As circuit technology advances to new levels of integration, transputers will increase the amount of processing, memory, communications, and concurrency within the same architecuture.

The architecture is based on the process model of computing. This model views a process as an independent computation, with its own program and data, which can communicate with other processes being executed at the same time. Communication is by message-passing through explicitly defined channels. Communication between processes is separate from communication between processor and memory. This is important when communication is between processors of different speeds.

A set of concurrent processes can be implemented on a transputer through the use of special instructions which share the processor time between the concurrent processes while performing interprocess communication. It is also possible to program systems containing multiple interconnected transputers in which each transputer implements a set of processes. Such a set of processes can be mapped onto a multiprocessor system to minimize cost, to optimize throughput, to maximize responsiveness to specific events, or to achieve some other advantage.

The transputer can be programed in most standard programing languages. In addition to Occam, compilers will soon be available for FORTRAN, C, and PASCAL. However, Occam is designed to best exploit the concurrency and communication possibilities in the transputer. Compiled Occam is as efficient as hand coding by an expert programer, so there is no need for an assembly language.

Occam can be used to exploit concurrency by encapsulating the input, output, and interrupts within a simple formalism. The language may be used to program an individual computer or a network of computers. In a single computer, the computer shares its time between concurrent processes, and the channels are implemented by values in store. In a network, each computer with local store executes a process with local variables, and each connection between two computers implements a channel between two processes. A program designed for a network of connected computers may be executed unchanged by a single computer.

Occam may be used alone or as a link between modules written in other high-level languages, thereby enabling them to run concurrently.

The transputer architecture is word-length independent; therefore transputers of different word length may be freely interconnected and programed as a single system.

Physical and Logical Aspects of the Architecture. The transputer uses point-to-point communication links. Each transputer has one or more standard links, each of which may be connected to a link of some other component. Thus, transputer networks can be of arbitrary size and topology.

In point-to-point communication there is no contention for the communication mechanism. There is no capacity load penalty as the number of transputers in the system is increased. The larger the number of transputers in the system, the higher will be the total communications bandwidth of the system. All connections between transputers are short and local.

As each transputer has its own local on-chip memory and memory interfaces are not shared, they can be individually optimized on different transputer products to exploit very large-scale integration, providing high bandwidth with the minimum of external components.

Each transputer link provides one channel in each direction, which allows an application design, represented in Occam to be directly mapped onto an appropriate network of transputers. Communications through any one link may occur concurrently with communication on all other links and with program execution. Synchronization of processes at each end of a link is automatic and requires no explicit programing. Communication between processes is the same whether executed on different transputers or on a single transputer.

Each link of two channels carries input and output data and link control information serially. A message is transmitted as a sequence of 8-bit bytes. The communication protocol synchronizes the transmission of each byte of data, thus ensuring that slow and fast transputers can communicate reliably. All transputers support a standard communications frequency of 10 MHz, regardless of processor performance. Transputers of different performance can be directly connected, as can additional future transputers.

Link communication is independent of clock phase, and independently clocked systems can still communicate.

A number of link adaptor devices provide a means of interfacing transputer links to nontransputer devices; e.g., dynamic random access memory (DRAM) chips. The on-chip memory of the transputer is static RAM.

A peripheral control transputer, such as a graphics or disk controller, has interfaces tailored to the requirements of the specific device.

Each transputer has a timer, and Occam permits the current value of the timer to be read, a process to be delayed until the time reaches a certain value, and timeouts to be constructed. This is useful in real-time systems.

After reset, a transputer waits for the first message to be received on a

link, and interprets the first message as a program to be loaded and executed. This provides the standard mechanism for bootstrapping a network of transputers.

The Occam Language. Occam enables a system to be described as a collection of concurrent processes which communicate with each other and with peripheral devices through channels. The three primitive processes in Occam are:

- Assignment, which changes the value of a variable
- Input, which receives a value from a channel
- Output, which sends a value to a channel.

Processes are combined to form sequential, parallel, or alternative constructs:

- "Sequence" means that the component processes are executed one after the other
- "Parallel" means that the component processes are executed together
- "Alternative" means that the component process which is ready to communicate first is executed.

A construct is a process and may therefore be used as a component of another construct. Conventional sequential programs can be expressed in Occam using variables and assignments, combined to form sequential constructs. Concurrent programs may be expressed in Occam using channels and inputs and outputs, which are combined to form parallel and alternative constructs.

Each channel provides a one-way connection between two concurrent processes. When communication is synchronized and one channel is used for input in one process and output in another, communication will take place when both processes are ready. The value to be output is then copied from the outputting process to the inputting process.

As stated earlier, Occam can be used as a harness to link modules written on other high-level languages. However, to gain the most benefit from the transputer architecture the whole system can be programed in Occam. This allows the same concurrent programing techniques to be used for both a network and a single computer. Thus, a program ultimately intended for a network of transputers can be compiled and executed efficiently by a single computer used for development.

Occam also provides a clear notion of logical behavior, as the logical behavior of a program is not altered by the way in which the processes are mapped onto processors or by the speed of processing and communication.

The configuration of a program to meet real-time constraints is provided by annotations to the parallel and alternative constructs. For parallel constructs, the components may be placed on different processors, or may be prioritized. For the alternative construct, the components may be prioritized.

Comments

The only transputer that has been delivered is the T414, first delivered in October 1985. It has a 32-bit microprocessor, four standard communication links, and 2-k bytes of memory on chip. Its performance is 10 million instructions per second. The four twin communication links, operating at 10 million bits/second are used to link directly to other transputers or to some other component such as dynamic RAM.

Both the T414 and the T424, to be available soon, with 4-k bytes of on-chip memory are fix-point processors, which means that floating point operations have to be programed. However, a floating point processor F-424 is expected to be available by the end of 1986. This will substantially speed up floating point operations, hence performance, on large systems designed for large amounts of numerical computation.

The flexibility and compactness of the transputer make it a remarkably useful building block for large parallel systems. This fact has been recognized in the plans for the EEC-sponsored large high-performance system for numerical applications under development at Southampton University, UK (*ESN* 39-6:252-255 [1985]). This system will use the F424. At Imperial College, London, the T414 or T424 will be used for the Alvey program sponsored fifth generation computer designed for the processing of programs in logic or functional languages (*ESN* 39-9: 418-421 [1985]). Floating Point Systems (FPS), Bracknell, UK, announced in April 1986 the FPS T series of high-speed parallel processors, which will use the transputer as its building blocks. It was announced as the world's fastest computer. The low price and high performance of the transputer used in commercial computing systems will probably have a major impact on the cost/performance of such systems.

6/20/86

CONFERENCE ON PYRAMIDAL SYSTEMS FOR IMAGE PROCESSING AND COMPUTER VISION

by J.F. Blackburn.

Introduction

This conference, held from 5 through 9 May at Maratea, Italy, was sponsored by the NATO Panel on Sensory Systems for Robotic Control. There were 38 participants from 10 countries including: Italy (13), US (8), Germany (4), France (3), UK (3), Austria (2), Turkey (2), and one each from Hungary, India, and Israel.

As the title suggests, the main purpose of the workshop was to assess the suitability of pyramidal computer systems for image processing and computer vision. These applications require very large storage of data and very high computational capability. Also, the architecture and processing techniques heavily influence the performance of computer systems in these specialized applications. A growing number of computer scientists believe that the hierarchical nature of processing in a pyramidal system is well adapted to image processing.

Typically a pyramidal computer system has several layers of processing elements (PE's) arranged in a square array of 2^n PE's; e.g., a 16×16 array for 256 PE's. The level above would contain 64 PE's in an 8×8 array, above which would be a 4×4 array, a 2×2 array, and a single PE at the apex of the pyramid. Other arrangements are possible, but this one represents a classical example.

A PE can communicate with neighboring PE's on its own level, with a parent on the level above and, typically, with four children on the level below, except of course for the bottom layer.

The papers presented covered architecture, applications, programing, simulation, and performance expectations. Out of a total of 29 papers given, seven seemed to me of particular value. These I have summarized in the sections which follow.

Pyramidal Systems: Architectural Futures

V. Cantoni, Department of Computer Science and Statistics, Pavia University, Italy, highlighted four processing stages. These are: preprocessing, primitives extraction, symbolic description, and interpretation. A variety of ways to accomplish these four stages in a hierarchical way have been proposed. They follow a bottom-up approach in which control flows from low-level image processing to high-level image processing, and each step performs its processing or manipulating independently and passes its output to the next stage. Alternatively, in a top-down approach the operation is goal-oriented and the exchanges are from high-level towards low-level image processing. A more general approach allows inconsistencies to be considered and solved by feedback effects to the previous stages.

The single-instruction, multiple-data (SIMD) structure is well suited for the low-level steps that deal with image-to-image transformations, and identical operations applied to all pixels. The multiple-instruction, multiple-data (MIMD) structure is better suited to data-dependent asynchronous operations at the higher levels.

A variety of hierarchical solutions for image-processing pyramidal systems have been proposed. Five families of such solutions are:

1. Heterogeneous/centralized, consisting of a single SIMD processor for low-level image processing and a separate MIMD processor for high level.
2. Heterogeneous/closely distributed, in which a SIMD subsystem is devoted to each PE of the MIMD structure.
3. Heterogeneous/loosely distributed, in which the two subsystems are physically distinct and linked through as many buses as PE's in the MIMD part.
4. Homogeneous/compact pyramid, in which several layers of identical PE's work autonomously in SIMD mode.
5. Homogeneous/distributed pyramid, which uses a small number of identical, powerful PE's arranged hierarchically so as to represent a pyramid.

The objective of a national research program involving research groups from the universities of Pavia, Rome, and Milan and the National Research Council of Palermo is the building of a new system based on a compact pyramid of homogeneous processors. A multi-SIMD architecture is implemented. If all the PE's execute the same instruction, the pyramid follows the natural SIMD mode, but when a layer masking facility is used some coplanar PE's may be inhibited and a PE masking register may disconnect a chosen subset of all the active PE's. In this way, the machine may operate in a data-dependent mode.

In parallel execution of image processing algorithms a control structure can terminate recursive instructions by means of a global Boolean or by having as inputs all the single-state conditions of the PE's belonging to a single layer. This is called an *OR sum tree*.

Complete overlapping of input/output and processing is done in the system. Images enter the pyramid at the desired plane in column parallel fashion; meanwhile, processing goes on as dictated

by the first main clock and is interrupted only for one cycle of the second clock to store a complete bit plane in the PE's local memories.

Horizontal interconnection among PE's of the same layer and vertical linking PE's of different layers are implemented.

The main applications being developed at Pavia are: a partial differential equation solver, a planning strategy, and object recognition techniques.

Pyramidal Transforms in Image Processing

The paper by P.W. Besslich, University of Bremen, Germany, dealt with a class of transform algorithms suitable for generation and processing of pyramidal data. The transformations make use of radix-2^k signal-flow graphs and "in-place" processing. The scheme is based on a hierarchical ordering of a $2^n \times 2^n$ data array in memory for radix-2 signal-flow graph processing, or alternatively, on linewise-stored data using incomplete radix-2^k graphs ($k=1, 2, \ldots, n$). Generation of pyramidal data structures is a special case of a more general class of two-dimensional (2D) transformations that calculate 2D transform coefficients hierarchically; i.e., from the coefficients of subareas. Various useful global or local transformations may be implemented under the hierarchical scheme. Pyramidal data structures were shown to be a special case of hierarchical transforms; e.g., each node level of a quad-tree/averaging pyramid corresponds to a hierarchy level of a reversible transformation. From the class of orthogonal transformations the 2D Walsh-Hadamard transform complies with the stipulations of hierarchical generation of coefficients. Local versions of pyramidal radix-2^k transformations provide windows of size $2^k \times 2^k$. It was shown that windows of odd-numbered dimensions require transformations based on radix-p (p = prime number > 2). Local pyramids using weighted and overlapping window operations were shown to allow various weighting functions of the window; e.g., a Gaussian weighting. Pyramidal transform algorithms may be supported by special hardware. An architecture was proposed that uses spatially parallel processing and macropipelining for rapid generation and processing of pyramidal transforms.

Multicomputer Architectures for Pattern Perception and Artificial Intelligence

The presentation by Leonard Uhr, University of Wisconsin, concentrated on the development of appropriately process-structured architectures for the perceptual recognition of real-world objects in real time. Structures appropriate for other areas of Artificial Intelligence were discussed and generalization of these systems was explored.

The perception program can be represented as a data-flow graph, and the problem of developing an appropriate multicomputer topology can be treated as one of finding a multicomputer that can efficiently execute that graph as it scans over it. A one-node graph (corresponding to a single central processing unit computer) can scan over any graph, but it requires much time. A 1D pipeline can effectively execute local operations on arrays of iterated information of any dimension, reducing the time needed by the length of the pipe. A 2D array can handle 2, 3, ..., N-dimensional arrays with speed-ups proportional to the number of processors; however, they can be slow at moving information simultaneously for global operations. A pyramid of arrays has the capabilities of an array and also good properties for global operations.

Pyramids can be used with great potential power and efficiency by treating them as 2D pipelines through which information flows and is successively transformed. Several different types of complex objects have been successfully recognized in this way. There are a number of possible augmentations--internal to the pyramid and in the form of additional networks of computers--to which the pyramid can be linked. These offer promise of increasing the power of the pyramid and also of making the total system more generally useful.

An important application of pyramid systems is that of visual perception--an extremely difficult problem involving:

- Recognition and description of scenes of complex moving objects
- Handling the enormous amount of information needed to resolve complex scenes
- Recognition of highly structured objects over unknown variations
- Robustness sufficient to overcome errors in the face of distortions
- Great speed, as when robots interact in realistic surroundings.

The major alternative software approaches are to:

- Combine results of independent feature detectors
- Assess syntactic structures over primitives
- Match models stored in memory with appropriate regions in the image
- Hierarchically examine successively larger structures.

As mentioned before, pyramids can be used with great efficiency. A pyramid of

arrays can be viewed as a tree linking successively smaller arrays. Each array can execute all array operations efficiently, and messages can be passed between arrays. Information can be compressed as it is transformed, and potential bottlenecks can be eased with more hardware.

General Purpose Pyramidal Architectures

Gerhard Fritsch, University of Erlangen, West Germany, said that in many numerical applications there is a natural local interaction. For example, in the discretization of a system of partial differential equations which describe a physical phenomenon, the space and time continuum is replaced by a spatial grid and a sequence of time steps. Continuous physical variables are replaced by 2D or 3D arrays of values. By use of some relaxation method, we obtain, by iterations, an approximate solution of the mathematical problem. Such problems demand nearest-neighbor processing structures which can be realized by orthogonal grids of processor-memory modules (PMM's). In 2D- or 3D-processor arrays each PMM has four or six neighbors, respectively. Even though best data mapping could be achieved on 3D-processor arrays, 2D-processor arrays are preferred for practical reasons, and 3D data meshes can be computed by 2D-processor arrays, layer by layer.

Other requirements, including user problem computation, higher operating system functions. and overall control, lead to a variety of possible architectures. Included are pyramidal systems of hierarchically ordered processor arrays, a processor array with one PMM having master function, and others.

Conclusions based on experimental systems developed at Erlangen are as follows. For general purpose use (rather than special applications) the computer architecture must have suitable features that allow for efficient computations of user problems whose parameters vary widely. Fundamental features are regularity and homogeneity of the multiprocessor structure, an effective interconnection network for the processor and memory modules, and an hierarchical order of the system components according to their function.

Distributed shared memory systems generally have a regular distribution of processing elements and attached memories. Data are stored where they are needed for processing. Furthermore, distributed shared memory systems profit from tight coupling between neighboring PMM's, the use of a multiprocessor operating system with a straightforward structure, and ease of user programing.

Pyramids: Expected Performance

The paper by M.J.B. Duff, University College, London, UK, concentrated on algorithmic constraints and language constraints in comparing pyramids with other types of architecture.

Of great importance in image processing is the deliberate correspondence between the structure of the computer and the structure of key features of algorithms commonly executed by the computer. This is of particular importance in local neighborhood operations in which a new value for each pixel is calculated as a function of the previous values of the subset of pixels forming a local neighborhood to the pixel being revalued. Three aspects of these operations are important with respect to optimization:

1. The operation can be performed simultaneously on every pixel in the image.
2. Since data is required from every pixel in the local neighborhood, a further degree of parallelism results from a parallel fetch.
3. It is natural to maintain the pixel array structure before, during, and after the operation to avoid overheads.

The aims of the system design should include a processor that would be assigned to each segment resulting from the spatial or temporal decomposition of the operation. Each processor should:

1. Communicate directly with the sources of the data needed for the task it is to perform.
2. Communicate directly with the destination for the results of its operation.
3. Be kept usefully busy for the majority of the time.

It is also useful to configure the computer hardware so that the structural features of a programing language relate naturally to the computer structure. However, it is not yet clear (particularly in image processing) whether styles of programing, like functional programing, data flow programing, and concurrent programing, will have an advantageous or counter-productive effect in terms of overall performance of a system.

When a pyramidal system is compared with a flat array we must consider the need for each processor in a pyramid to make connections with one processor on the level above and four processors on the level below.

If a pyramid is treated as a pipeline of flat arrays with automatic resolution between the stages, a separate controller will be needed for each level

(i.e., 1 + log N controllers where N is the number of levels).

The greatest strength of pyramids is in multiresolution processing. Typically, resolution reduction involves forming averages of 2×2 pixel subareas of the image. Here the pyramid shows an advantage over the flat array in that valid pixels do not have to be compacted into a contiguous array after computation.

In his conclusion, Duff said that pyramids do not seem to offer substantial advantages over flat arrays for low-level operations. For high-level operations, further experience and analysis is needed before a firm conclusion can be made. In short, the potential of the pyramid is still to be explored.

Programing Image Processing Machines

S. Levialdi, University of Rome, Italy, gave a completely new approach to the design of high-level image programing languages which is exemplified by integrated programing language (IPL). Its three components are logical (LIPL), interactive (IIPL) and physical (PIPL).

The central idea of IPL is to allow the user of the system to navigate comfortably in the data base by means of user-defined icons, windows, and ports. The image data base is hierarchical in nature and may be enriched with user-defined images by the explicit association of parts of existing images.

The main feature of IPL comes from the introduction of icons for exploiting visual feedback and perceptually significant computing metaphors. The icon is a symbol representing an object, or a set of objects, belonging to one of three classes: an object icon, a window icon, or a command icon. An icon's data may be recalled by naming the icon or by pointing at it with a mouse or a cursor.

An object icon may be specified by naming it or its object type and by specifying a rule defining its corresponding object set. Generally the object icon is associated with an icon port for its materialization, thus allowing the icon to be loaded into the workspace through the chosen icon port. Window icons enable visual zooming into any part of the image. A window may be a rectangle, sector, circle, corridor, or polygon. Windows also have attributes which specify their location, extent, and orientation.

Icon windows and ports are driven by commands or activated by cursor commands (like "port cursor"). The main principles underlying the image retrieval process imply the notion of logical images, which are a collection of picture objects and relational objects. The picture object is a set of attribute triples (a-name, a-type, eval-rule); a picture object class is a set of picture objects having the same type since a picture object class always has a unique type.

The evaluation rule may present the pixels in numerical form or in grey-level form. The evaluation rule may act when an attribute value is specified so as to interpret it and present the object to the user, or it may interpret the object to the user, or it may interpret vertical attributes (for instance when these attributes must be computed after an image-processing algorithm has completed its task).

Two interesting milestones in programing language development are the extension of high-level structured languages and the concept of an integrated language able to cope with all the functions required in an image information system.

Pyramid Algorithms for Perception Organization

A. Rosenfeld, University of Maryland, presented his paper on pyramid algorithms for perception organization. Multiresolution, or pyramid, approaches to computer vision provide the capability of rapidly detecting and extracting global structures such as features, regions, or patterns from an image. The human visual system, too, is able to spontaneously, or preattentively, perceive various types of global structure in its input; this process is sometimes called perceptual organization. Pyramid-based algorithms can detect and extract these types of structures. Such algorithms include those for inferring 3D information from images and for processing time sequences of images. If implemented in parallel on cellular pyramid hardware, these algorithms require processing times on the order of the logarithm of the image diameter.

In summary, the bottom-up approach to analysis of the image includes:

- Summarizing the intensity data (plane fitting, statistical analysis [modality/anomaly detection])
- Detecting features (edges, curves, spots)
- Summarizing feature maps (texture analysis)
- Summarizing contour data (continuation-based grouping, line fitting, statistical analysis)
- Detecting closed contours (blobs, ribbons)
- Summarizing ribbon data.

In summary, the top-down approach requires:

- Delineating detected features
- Filling closed contours (segmentation techniques)
- Return to bottom-up.

The approach followed is to rapidly compute global information about an image in a recursive fashion. The computations performed involve model fitting rather than filtering. The four key aspects of the approach are:

1. It provides a unified method of detecting various types of global pattern by bottom-up recursive fitting of low-order polynomial models to the data.
2. It provides a method of delineating the detected patterns by top-down recursive refinement of the fitted data.
3. It allows for the detection of more complex types of global patterns by applying local feature-detection processes to the fitted models.
4. The methods can be applied to grey-level surface, to edges or curves, or to vector-valued data such as disparity or optical flow fields.

The transition from local to global--from pixel arrays to descriptive data structures--has traditionally been a major point of discontinuity in vision systems. The approach Rosenfeld described may make the discontinuity less abrupt.

General Comments

This workshop on pyramidal systems for image processing brought together the foremost investigators on this subject in Europe and the US. Although only seven of the 29 papers are summarized in this article, most of the papers were good and relevant to the conference purpose.

The complete program is given below in Table 1. A publication containing the entire proceedings is expected to be available in December 1986. It can be obtained by writing to Dr. Mario di Lullo, NATO Scientific Affairs Division, B-1110 Brussels, Belgium.

Table 1

Program

Algorithms and Architectures

Cantoni, V., Pavia University, Italy, "Pyramidal Systems: Architectural Futures."
Castan, S., Paul Sabatier University, France, "Architectural Comparison."
Dyer, C., University of Wisconsin, "Pyramidal Algorithms II."
Foglun, J., Hungarian Academy of Sciences, Budapest, Hungary, "Systolic Automata."
Fritsch, G., University of Erlangen, West Germany, "General Purpose Pyramidal Architectures."
Kroputsch, W., Institut für Digitale Bildverarbeitung und Graphik Forchungs Gesellschaft, Joanneum, Austria, "Pyramidal Algorithms."
Schaefer, D., George Mason University, Virginia, "The GAM System."
Stout, G.G., University of Michigan, "Hypercube Computer."
Tanimoto, S., University of Washington, "Pyramidal Algorithms."
Uhr, L., University of Wisconsin, "Vision Cones."

Applications

Burt, P., RCS, Princeton, New Jersey, "Pyramid Hardware Applied to Surveillance."
Dengler, J., Heidelberg University, West Germany, "Motion Analysis with the Dynamic Pyramid."
Majunder, D., Indian Statistical Institute, India, "Fifth Generation Computing."
Merigot, A., University of Paris, France, "A Pyramidal System for Image Processing."
Peleg, S., Hebrew University, Israel, "Graphics via Pyramids."
Pinz, A., Austria, "Applications of Expert Systems."
Rosenfeld, A., University of Maryland, "Multi-resolution Computation."
Sharawy, I.M., UTC Center, France, "Image Processing with CCD Arrays."
Stansfield, S., University of Pennsylvania, "Tactile Information Processing."

Analysis and Implementation

Besslich, P., University of Bremen, West Germany, "Pyramidal Transforms in Image Processing."
Blanford, R., University of Washington, Seattle, "A Pyramid Simulator."
Duff, J.B., University College, London, UK, "Pyramids: Expected Performance."
Ferretti, N., Pavia University, Italy, "Simulation of Overlapping Pyramids."
Gerardi, G., Palermo University, Italy, "Hardware for the PAPIA Controller."
Maloberti, F., Pavia University, Italy, "VLSI Implementations."
Negrini, R., Milan Polytechnic Center, Italy, "Fault Tolerance Problems."
Zimmer, H., Stuttgart University, West Germany, "Declarative Features in Pyramids."

Languages

Di Gesu, V., Palermo University, Italy, "A Language for PAPIA."
Levialdi, S., University of Rome, Italy, "High Level Languages."

7/02/86

Mechanics

FLUID MECHANICS RESEARCH AT DFVLR

by Eugene F. Brown. Dr. Brown is the Liaison Scientist for Fluid Mechanics in Europe and the Middle East for the Office

of Naval Research's London Branch Office. He is on leave until September 1987, from the Virginia Polytechnic Institute and State University, where he is a Professor of Mechanical Engineering.

The Deutsche Forschungs-und Versuchsanstalt für Luft-und Raumfahrt (DFVLR) is the principal German aerospace research organization. It has a total staff of some 3400, approximately half of whom are scientists and engineers. It is divided into seven departments including Flight Mechanics/Guidance and Control, Materials and Structures, Energetics, Telecommunications Technology and Remote Sensing, Scientific Technical Facilities, Project Management, and Fluid Mechanics (*ESN* 39-3:115-120 [1985]). The Fluid Mechanics Department is composed of four institutes: The Institute for Design Aerodynamics, The Institute for Propulsion Technology, The Institute for Theoretical Fluid Mechanics, and The Institute for Experimental Fluid Mechanics. This article describes my visit to the Institutes of Theoretical Fluid Mechanics and Experimental Fluid Mechanics, both of which are in the city of Göttingen, a university community located approximately 100 kilometers south of the city of Hannover. These two institutes, along with the nearby Max Planck Institute for Flow Research, were founded by Ludwig Prandtl in the early part of this century.

Institute for Theoretical Fluid Mechanics

The Institute for Theoretical Fluid Mechanics is headed by Professor H. Oertel and is composed of four divisions: Instabilities and Separation, Transition and Turbulence, Aerodynamics, and Computational Fluid Dynamics. Of the 220 personnel at DFVLR working in the aerodynamics area, 40 (including 30 scientists and engineers) work in Oertel's institute. Their principal computational facility is a CRAY-1S, located in DFVLR's computer center in Oberpfaffenhofen. Two possibilities are being explored to upgrade this facility: either outright purchase of a CRAY-2 by DFVLR or sharing a CRAY-2 which has already been scheduled for installation at the University of Stuttgart. Among the numerical codes in current use at the institute are finite volume codes for three-dimensional Navier-Stokes calculations, finite-difference codes for hypersonic flow problems, and spectral methods for turbulence transition calculations.

The Laminar Wing Project. Oertel's institute is a significant contributor to the international aerodynamic research project on laminar wings. This project is supported by the Deutsche Forschungsgemeinschaft (DFG), the Bundesministerium füer Forschung und Technologie (BMFT) and the German Ministry of Defense. In connection with this project, two major experiments are being carried out to provide a high-integrity data base which numerical modelers can use to develop and validate their codes. The first experiment involves determining the influence of the pressure gradient on the onset of cross-flow instabilities and secondary instabilities on a flat-plate boundary layer. The second experiment involves a three-dimensional swept wing.

The wing which will be used in these experiments has laminar profile which, on the basis of two-dimensional calculations, is designed to produce shock-free flow at a free-stream Mach number of 0.78. The wing has 20° of sweep, a symmetrical cross section, and an aspect ratio of 9. (See Figure 1.) The coordinates of this wing have been described by analytical functions in a recent paper by Sobieczky (1985) of the Aerodynamics Division in which these functions are used to provide the coordinates of the wing at 4000 surface points. The fabrication of the wing (with a span of 0.65 m) based on these functions has recently been completed. The next step will be

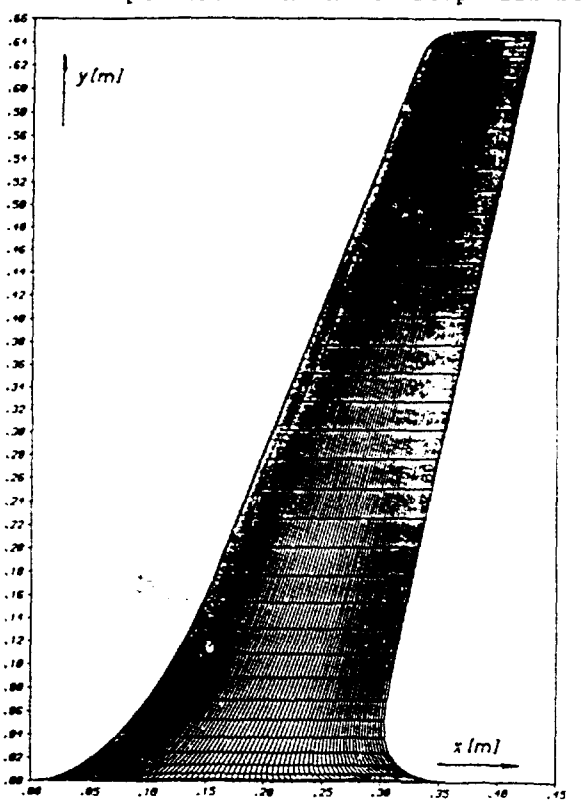


Figure 1. Geometry for swept wing experiment.

to modify these functions to take into account the actual dimension of the manufactured wing. Tests will be conducted in DFVLR's $1 \times 1\text{-m}^2$ transonic wind tunnel at zero incidence and at angles of attack of up to 2°. In addition to the usual surface static pressures, complete LDV surveys will be made upstream and downstream of the airfoil in order to provide complete documentation both within and on the surfaces of a control volume appropriate for use in computational fluid dynamics calculations. This data will then be used as the basis for a workshop in 1988 at which selected individuals will be invited to present the results of their calculations based upon conditions measured at the inlet and exit planes and on the wind tunnel walls. At the meeting, the predicted surface pressure measurements on the airfoil and the predicted lift and drag calculations provided by the authors will be compared with measured results.

Also involving the laminar wing project are three-dimensional transition investigations aimed at determining local stability criteria in compressible three-dimensional flows. This work, being carried out in the Transition and Turbulence Division by Dr. L. Kleiser, involves the numerical integration of three-dimensional time-dependent Navier-Stokes equations. In his calculations, he has investigated the early stages of laminar/turbulent transition in both boundary layer and Poiseuille flows. The equations were integrated using a spectral method, periodic-type boundary conditions, and a computational frame of reference attached to the Tollmien-Schlichting waves. He has recently extended his calculations to simulate the effects of boundary layer control by blowing and suction. Kleiser presented these results (1985) in last fall's GAMM Conference on Numerical Methods in Fluid Mechanics (see ONRL report C-1-86); they showed that two-dimensional control works well during the initial transition stages, but once significant three-dimensionality has developed, transition can no longer be prevented by two-dimensional means.

Three-Dimensional Separated Flows. Another national aerodynamics research project to which DFVLR is contributing is three-dimensional separated flows. This work is being carried out in the Computational Fluid Dynamics Division, headed by Dr. W. Kordulla. The principal activity of the group is developing three-dimensional Navier-Stokes calculations using both implicit methods and Runge-Kutta time stepping. Kordulla has worked closely with MacCormack at Stanford University and is currently involved in applying MacCormack's new unfactored implicit scheme. Recent calculations have included an RAE 2822 airfoil and a hemisphere-cylinder in transonic flow. The purpose of the hemisphere-cylinder (done at both zero incidence and angles of attack of 19°) was to compare computed three-dimensional separation patterns with the topological descriptions developed by Dallmann (1983). Although some doubt remains about whether the grid is sufficiently fine--and some anomalies were discovered regarding the stability of the flow--the results (see Figure 2, for example) showed that the numerical simulation yielded results consistent with possible topological structures. Kordulla is presently incorporating the K-ε turbulence model into his calculations (in place of the Baldwin-Lomax model) and adding a total variation diminishing (TVD) feature to increase the robustness of the calculations. His intention is to then apply the modified MacCormack scheme to the calculation of the swept wing designed by Sobieczky.

Institute for Experimental Fluid Mechanics

Separated flows are also being studied in the Institute for Experimental Fluid Mechanics, headed by Professor H. Hornung. Hornung's institute is comprised of a technical staff of about 80, of which 40 are engineers and scientists. The institute is divided into the divisions of Measuring Techniques, Subsonic Boundary Layer Flows, Cascade Flows, Real

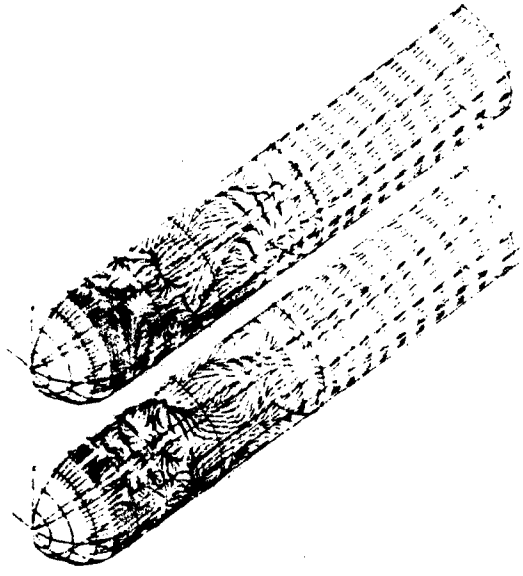


Figure 2. Skin friction line pattern on the wall of a nominally axisymmetric flow at two different times $M_\infty=0.9$, $Re=212500$.

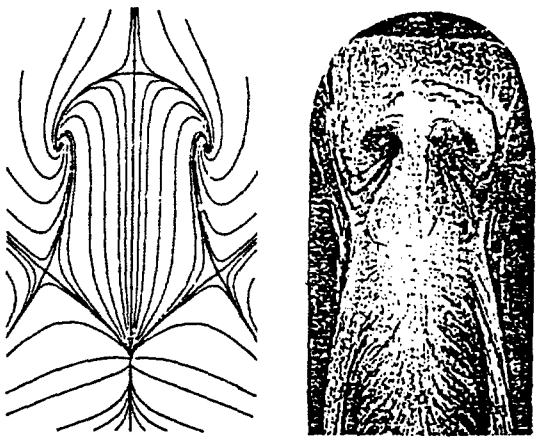
and Rarified Gas Dynamics, and High Speed Flows. The majority of the institute's support comes from the BMFT (similar to Oertel's institute) with lesser amounts (10 to 25 percent) being contributed by the local state government, the German Ministry of Defense, and various industrial contracts.

Topological Study of Separated Flows. In a collaborative activity between Hornung and Professor A. Perry of the Department of Mechanical Engineering at the University of Melbourne, a topological study of separated flows has been carried out involving local solutions of the Navier-Stokes and continuity equations. The technique employs the so-called critical point theory which was originally developed for the study of nonlinear dynamic systems. (A critical point is a point where the streamline slope is indeterminate.) First employed for fluid mechanics calculations by Oswatitsch, Lighthill, and others in the early 1960's, it has recently been extended by Perry to "clusters" of critical points and to series expansions of arbitrary order. In this form the technique is suitable for examining the topology of both steady and unsteady separated three-dimensional flows. The advantage of the technique is that solutions of extremely high resolution can be obtained in the vicinity of these critical points without having to produce a complete solution of the Navier-Stokes equations.

Perry uses a series expansion of the velocity field to derive ordinary differential equations for the expansion coefficients after first expressing the Navier-Stokes equations in vorticity-transport form. The procedure for obtaining these coefficients is quite complex. However, the authors have discovered how to generate separation patterns with great control over their scale and topological properties. Figure 3 shows the results of one of their calculations showing a separation pattern known as an "owl face of the second kind." This is a topology similar to the hemisphere-cylinder skin friction line patterns obtained from Kordulla's calculations. The usefulness of the calculations is to aid in the interpretation of complex flow patterns obtained both from calculation and experiment.

An investigation of separated flow of interest to Hornung's group but actually carried out by G. Schewe of the Institute of Aeroelasticity, was the two-dimensional separated flow behind a circular cylinder. In these studies, DFVLR's pressurized low-speed wind tunnel was used. This allowed Reynolds numbers from 2.3×10^4 to 7.1×10^6 to be achieved on a single model. The results, described by Schewe (1983), revealed two discontinuous transitions in the transcritical Reynolds number range, one at the Reynolds number of 3×10^5 and the other at a Reynolds number of 3.5×10^5 (see Figure 4), where only a single transition was previously believed to exist. The instrumentation consisted of a sophisticated piezoelectric balance possessing a high natural frequency, a large dynamic range, and a low interference. The source of the two discontinuities was traced to laminar/turbulent transition occurring first on one side of the cylinder and then on the other.

The Adaptive-Wall Wind Tunnel Facility. One of the institute's most unusual facilities is the High Speed Flow Division adaptive-wall wind tunnel designed by E. Wedemeyer. The test section was fabricated from a 0.8-m-diameter 2.4-m-long thick-wall rubber tube which is externally supported by 64 jacks,



(a) Computation (b) Experiment

Figure 3. Owl face of the second kind.

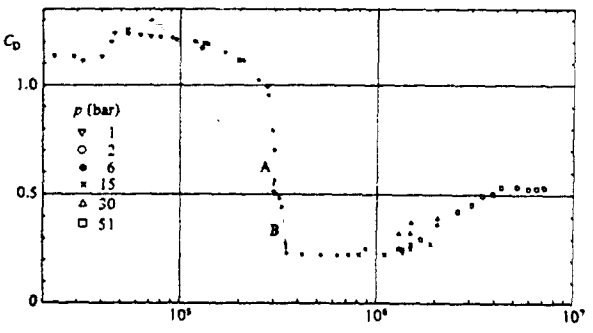


Figure 4. Drag coefficient showing the two discontiniuties, A and B.

located at various positions around the circumference of the tube, which can be independently positioned with stepping motors. The jacks are used to produce a wind tunnel wall shape equivalent to that which would exist if the model were tested under free-flight conditions. In principle, this allows interference-free conditions to be achieved in a much smaller wind tunnel than if a conventional (fixed-wall) wind tunnel were used. The unique feature of Wedemeyer's tunnel is that the rubber test section allows the walls to be adapted in three-dimensions rather than just two. (The usual implementation of the adaptive wall concept is to a two-dimensional test section in which only the upper and lower walls are moved.)

There is no doubt that the concept works. Results obtained in the adaptive wall tunnel for both two-dimensional and three-dimensional models have been shown to be essentially identical with results obtained in the 30-times bigger pressurized wind tunnel (PWT) at the Arnold Engineering Development Center. Although additional tests are planned, Wedemeyer told me that in the future DFVLR might return to a two-dimensional design. The reasons for this are that the three-dimensional wall adjustment mechanism is complicated, the rubber walls have shown some lack of rigidity at high dynamic pressures, and there is no way that optical flow measuring techniques, such as LDV, can be used in such a test section because there is no way to install windows. Finally, recent investigations have shown that the growth of the side-wall boundary layer can be adequately controlled in a two-dimensional adaptive wall tunnel. Doubt about the ability to do this was the principal motivation behind the three-dimensional design.

The Cryogenic Wind Tunnel Facility. The High Speed Flows Division is also responsible for the design of DFVLR's new Ludwig-tube, cryogenic wind tunnel (Figure 5). Nitrogen will be used as the working fluid, and the design Mach number range is 0.2 to 1.2. The maximum Reynolds number is 95×10^6 (based on a model diameter of 200 mm). The 0.8-m-diameter, 130-m-long driver tube will give run times of approximately one second. The Ludwig-tube design will produce an extremely low level of free-stream turbulence. Another advantage of the design is that by comparison with conventional continuous-flow facilities such as the new European Transonic Wind Tunnel (ETW) and NASA's National Transonic Facility it is much cheaper to build and operate. The estimated construction cost is DM3 million ($1.4 million) compared with an estimated DM500 million ($230 million) for the ETW. The tunnel is now under construction and is expected to be completed sometime this year. Future plans include equipping the tunnel with a two-dimensional, adaptive-wall test section.

Summary

The Institute for Theoretical Aerodynamics and the Institute for Experimental Aerodynamics are very competent and productive research organizations. For example, the Institute for Experimental Fluid Mechanics published more than 200 papers in the past 2 years. In addition, the institutes have a strong commitment to international collaborative activities as demonstrated by contributions to international meetings and workshops, participation in international test programs, and activities in various international research organizations such as NATO's Advisory Group on Aerospace Research and Development (AGARD). The members of the scientific staff of these institutes have achieved international recognition for their research in such areas as computational fluid dynamics,

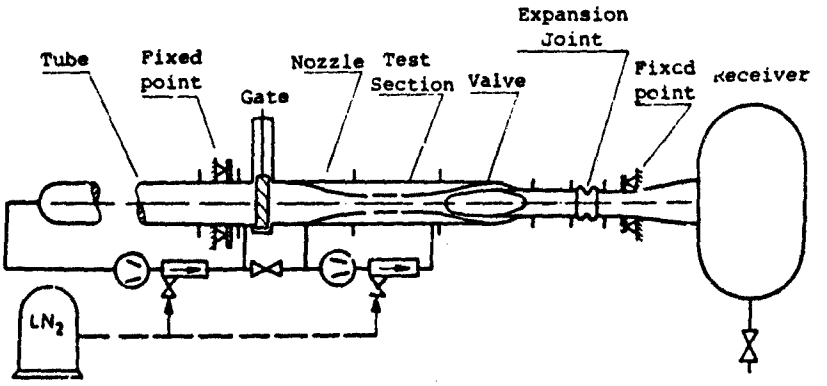


Figure 5. Cryogenic wind tunnel.

boundar[illegible]er transition, and separated flows. [illegible]eir well-established technical and experimental capabilities, combined with the capable leadership of Professor Oertel and Professor Hornung, will assure for these institutes an important role for fluid mechanics research in the years to come.

References

Dallmann, U., "Topological Structures of Three-Dimensional Vortex Flow Separation," *AIAA paper* (1983), 83-1735.

Kleiser, L., "Numerical Simulation of Laminar-Turbulent Transition," *Proceedings of EUROMECH 199, Direct and Large Eddy Simulation of Turbulent Flows* (West Germany: Technical University of Munich, 1985), 61-65.

Schewe, G., "On the Force Fluctuations Acting on a Circular Cylinder in Crossflow from Subcritical Up to Transcritical Reynolds Numbers," *Journal of Fluid Mechanics*, 133 (1983), 265-285.

Sobieczky, H., "DFVLR-F5 Test Wing Configuration for Computational and Experimental Aerodynamics," IB 221-85 A 22 (Göttingen, West Germany: DFVLR Institute of Theoretical Fluid Mechanics, 1985).

5/21/86

Physics

CURRENT UK TRENDS IN ATOMIC AND MOLECULAR PHYSICS REVIEWED AT THE ABERDEEN CONFERENCE

by Paul Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1987.

The University of Aberdeen, with assistance from the University of Stirling, organized the 17th National Atomic and Molecular Physics Conference of the UK. It took place from 7 through 10 April at the modern National Philosophy (Physics in contemporary English) Complex at the ancient King's College campus of the University of Aberdeen, Scotland. It was sponsored by the Atomic and Molecular Physics Subcommittee of The Institute of Physics, UK. The very perseverance of a two-decade-old national conference tradition casts doubts on the pronouncements made a year ago at the 2nd European Atomic and Molecular Physics Conference (see ONRL report C-4-85, or *ESN* 39-9:438-441 [1985]), according to which the success of the now regularly scheduled all-European conference makes regional and national meetings of this kind superfluous.

The Aberdeen conference was intended to give an overall picture of current preoccupations of the historically renowned British atomic physics community. If this intent were realized consistently, then it would appear that current emphasis lies in the area of atomic and molecular collisions.

There were 120 participants, almost all from the British Isles; but 11 scientists came from abroad: France, Italy, West Germany, Denmark, and the US. There were 11 invited papers (1-hour presentations) and 73 additional, specialized contributions. The latter were all presented in the poster-paper format; but, because ample time was alloted for these presentations and the space was not cramped, they were quite effective, often leading to animated minilectures.

Invited Talks

Essentially, all invited contributions were reviews, tutorials, or overall progress reports and, therefore, do not lend themselves to analytic reporting. I have selected those that I personally enjoyed most and will give a brief characterization of the areas covered by them.

The keynote address was presented by Professor N. Andersen (Aarhus University, Denmark). He gave a brilliant and well thought-out review on studies, both experimental and theoretical, relating to simple collision systems--light atoms or singly charged ions (mainly alkaline elements) as projectiles, and noble gases as targets. The review included his own very latest experiments on "perfect collisions." Detailed analysis led to a reevaluation (in fact, an amendment) of the so-called Massey criterion.

The presentation by Professor E. Merzbacher, the next speaker, currently visiting at Stirling University, UK (permanent address: University of North Carolina, Chapel Hill), complemented Andersen's presentation very well. He focused on the theoretical analysis of the high-energy end of ion-atom collisions (1-150 MeV phenomena) in a clear tutorial review presentation, discussing specific collision mechanisms. He concluded by pointing out that perturbative collision theory can be made to work amazingly well.

The third (and last) non-British guest speaker was Professor H.O. Lutz

(University of Bielefeld, West Germany) His report neatly balanced the other two talks of the day. He reported on ion-atom collisions, but concentrated on inner-shell ionization processes and payed much attention to laser-assisted collisions. The talk testified well to the remarkably high level of sophistication of current German research in atomic physics.

I think it was significant that the organizers felt it appropriate to invite precisely these three foreign scientists as guest speakers, all of them speaking on various aspects of one and the same topic, viz., ion/atom (or atom/atom) collisions.

Among the remaining invited talks was the highly animated presentation of Professor R. Donovan (Edinburgh University, Scotland), who talked about recent results in his laboratory concerning the production and the properties of so-called ion pair states of simple molecules, primarily iodine and various iodine-interhalides. As excitation is increased, this class of states decays into a pair of oppositely charged ions, and the ion pair states differ significantly from both the low-lying valence states and from the Rydberg states. In a sense, they bridge the gap on the road to polyatomic molecules. The studied ion pair states were produced with single-photon excitation, using synchrotron radiation, or with multiphoton excitation when powerful laser radiation was used. Apart from a wealth of basic physical insight that the ion pair states can supply, they may have the potential of enabling one to develop high efficiency, optically pumped inorganic dye lasers.

I very much enjoyed the clear and disciplined tutorial review by Dr. K. Taylor (Royal Holloway College, Surrey, UK) on atoms in strong magnetic fields. He made it clear that, in the range of external fields 1 to 10 tesla strong, Rydberg states and free states of atoms will show substantial consequences of the quadratic Zeeman effect. In fact, the term in the Hamiltonian which is proportional to B^2 becomes comparable to the Coulomb term if the electron distance from the core is a few thousand Bohr radii large. Taylor discussed several methods to solve the Schrödinger eigenvalue equation with a B^2 term and payed special attention to the expansion of the wave function in terms of Sturmian functions. He showed illustrations of several experiments which exhibited beautiful agreement with the calculations. Finally, he made the interesting comment that strong external magnetic fields should play an important role in charge-exchange reactions, since the neutral partner often goes through an intermediate Rydberg state.

Scholars in atmospheric physics may wish to take note of the work of Dr. P. Wraight (University of Aberdeen), who talked on atmospheric airglow excitation mechanisms; but I am completely incompetent to comment on this presentation.

The concluding invited talk was neither on atoms nor on molecules, but I was quite interested in it. Professor W.J. Firth (University of Strathclyde, Scotland) talked about free electron lasers (FEL). First, he gave an excellent tutorial on the Compton-regime FEL's (where the electron-wiggler interaction dominates over the electron-electron interactions). Then he described the UK's FEL laboratory which has been built near Glasglow and, as a major national effort, is home of a cooperative effort of several universities and national laboratories organized and directed by the Science and Engineering Research Council of the UK. The technical details of the equipment are now well known in the US both from the scientific and popular trade-literature journals. Suffice it to say that, except for the fact that it has much longer wiggler magnetic spacing, the British FEL resembles very much the one at Stanford University. The critical data are:

1. Source--an old linac electron source (30-100 MeV and 250 mA average current)
2. Number of wiggler magnets--76 (in four modules)
3. Number of electrons per RF cycle--about 10^8
4. Projected range of operation--2 to 20 μm, with a ±5 percent continuous tuning
5. Projected peak power--over 1MW
6. Average power--50W in CW operation.

After mentioning other details, Firth reviewed earlier experiments in which the simple, enhanced synchrotron operation (no phase matching: spontaneous emission) was tested. He dwelt, in particular, on the generation and test of higher harmonics. The clincher came next: Firth announced that only 2 weeks before (26 March 1986), the first successful experiment to demonstrate the FEL's operation as an amplifier was performed. The fed-in radiation came from a standard 10.6 μm CO_2 laser. Tuning was achieved (at fixed e-beam energy, around 50 MeV) by adjusting the wiggler field. The average gain was, admittedly, only 0.07 percent, but if and when the machine goes into complete laser oscillator operation an additional factor of 40 will become operative.

Current efforts are aimed, of course, to convert the equipment so as to achieve true (self-oscillating) FEL behavior. By way of summary, Firth told us that the correctness of the design has been proven and the demonstration of the physical properties was successful, but it is doubtful that the machine will ever become a true FEL facility. The causes of caution given are possible lack of funds and (though only obscurely hinted) all-out US competition.

Contributed Papers

The contributed papers were even less organized by subject than the invited papers. For the purpose of reporting, I have arbitrarily selected the following areas:

- Electron impact ionization
- Resonance phenomena
- Charge transfer
- Miscellaneous topics

From each, I have picked what I think are representative contributions.

Electron Impact Ionization. M.B. Shah, D.S. Elliott, and H.B. Gilbody (Belfast, Northern Ireland) developed a high-precision pulsed crossed-beam technique, incorporating time-of-flight analysis of the collision products. In this way they could study the electron impact ionization of simple atoms. The arrangement was such that it assured the measurement of the ionizing collisions in guaranteed absence of both electric and magnetic fields. The latest results, communicated at the meeting, have given the first truly high-precision measurements of atomic hydrogen impact ionization.

M.A. Chaudhry, A.J. Duncan, and H. Kleinpoppen (University of Stirling) in cooperation with R. Hippler (University of Bielefeld) determined the partial relative abundances of multiply charged ions formed when vacancies are produced in the L-shell of a noble gas atom by the impact of electrons with energies that are a few times larger than the L-shell ionization energy. The ions were analyzed by a time-of-flight spectrometer. They were detected either in coincidence with an electron resulting from the collision, or in coincidence with x-rays emitted by the ion. As an example, doubly differential cross sections for n-fold ionization (n=1,2,3,4) in argon versus the energy of the detected electron were presented.

In a related report, A.D. Bass, P. Hammond, G.C. King, and F.H. Read (University of Manchester, England) in cooperation with S.J.B. Buckman (University of Canberra, Australia) described their work on high resolution electron excitation functions for the lowest excited states of argon and krypton. They obtained experimental information on the cross sections of discrete states over a scattering-angle range 0° to 90°, with 1 eV to 2.5 eV above threshold (and with an energy resolution less than 20 meV). These measurements contribute significantly to the classification of negative-ion resonances.

Resonance Phenomena. The last two works described above lead us naturally to the research by I. Harrison and G.C. King (University of Manchester, UK), who investigated resonances associated with inner-shell excited states. In particular, these scientists studied inner-shell temporary negative ions in the elastic channel, and also, for the first time, in inelastic scattering channels. They presented elastic cross-sectional measurements in N_2, CO, and CO_2. In a certain CO state they discovered a new inner-shell temporary negative ion resonance at about 13 eV above the threshold of the excitation of the $^1\Pi$ and $^3\Pi$ states.

R.E. Palmer, J.F. Annett, and R.F. Willis (Cambridge University, UK) had something that I found very arresting. They observed negative ion resonances in inelastic electron scattering from diatomic molecules which were adsorbed intact on a solid surface. These resonances were seen in peaks of the cross section for vibrational excitation of N_2, CO, and O_2; these molecules were weakly bound on a graphite crystal surface at 10°K. The authors also analyzed prospects for organizing molecules into oriented arrays with distinctive angular scattering distributions.

Resonances in low energy (less than 100°K) collisions between He and formaldehyde were studied from the theoretician's viewpoint by J. Gerratt and G. Guthrie (University of Bristol, UK). The particular collision process has astrophysical significance in interstellar space. The researchers performed an R-matrix calculation with 13 radial basis functions and a maximum of 64 coupled channels. Resonance doublets were found in the region of 20 to 21°K, and then none up to at least 50°K. The resonances were of the Feshbach type, with formaldehyde intermediate states 2_{11} and 2_{12}.

Charge Transfer. The production and properties of excited xenon atoms formed in charge transfer collisions were the topic of an impressive presentation by M.J. Higgins and D.J. Latimer (University of Belfast, Northern Ireland). These authors produced fast beams of xenon atoms in the metastable state $6s'_{00}$, in the long-lived $5d_{12}$ state, and in Rydberg states (with n between 20 and 40). Their method was based on electron capture

collisions between Xe^+ ions and the inert gases H_2 and CH_3. The collisions occurred in the 2 to 25 keV range. The 6s' and 5d states were detected with the technique of laser photoionization to autoionizating states. Particular studies of the processes $5d_{1/2} \rightarrow nf'$ (with n up to 9) have been performed. Such processes may play an important role affecting the performance of noble gas excimer lasers. The Rydberg atoms, on the other hand, were detected by an adapted static field ionization technique. These states were found to be populated according to an n^{-3} rule, which is surprising since the collision velocities were rather low.

The intriguing possibility of producing population inversion by means of the reaction $H^+ + Na(3p) \rightarrow H(n=1) + Na^+$, and hence an H-based ultraviolet laser, was discussed by P.J. Allan, R. Shingal, and D.R. Flower (scientists from a Dansbury-Dunham, UK, cooperation). Energy defect considerations suggest that the above indicated charge transfer will occur primarily into the n=2 states of hydrogen, including the $\ell=1$ state; i.e., the 2p state. This state then decays radiatively, emitting the 121.6 nm Ly-α radiation. With this laser mechanism in mind, the authors computed charge transfer cross sections in a multichannel semiclassical impact parameter model calculation. Depending on the energy range, molecular orbital or atomic orbital expansions were used. The scientists found that for collision energies in the lab-frame energy range 200 eV to 500 eV there is a large cross section for capture into the H(2p) state from the excited Na atom, leading to large enhanced Ly-α emission. It should be mentioned that the present cross section calculations are in disagreement with some related calculations of other authors, as well as with experiments involving Na(3p). Thus, further direct experimental studies should be indicated.

Miscellaneous. In this subsection I pick two curios. The first, presented by J.N. Silverman (University of Stirling) in cooperation with D.M. Bishop (Ottawa, Canada) reported on a 20th-order perturbation study of the Stark effect for H_2^+. The unusual achievement of this work, extending recent interest in the study of hydrogenic ions in external fields, lies in the fact that it extended perturbative work from the 4th to the 20th order. Two parallel lines of investigations were followed. First, in order to obtain highest accuracy directly (with the need for making vibrational corrections), the Born-Oppenheimer approximation was not used; instead, the problem was treated nonadiabatically, viewing H_2^+ as a three-particle system with all constituents on an equal footing. Second, in order to demonstrate explicitly the large effect of the vibrational motion on the polarizabilities, the calculations were repeated within the Born-Oppenheimer approximation, with the nuclei clamped down at the equilibrium distance for the ground state. All calculations were made within the framework of the perturbational-variational Rayleigh-Ritz (PV-RR) matrix formalism. The numerical results were obtained with a flexible computer program fully exploiting the extension to high order via the generalized PV-RR remainder theorem, announced earlier by Silverman.

Finally, for the benefit of colleagues seriously interested in the age-old debate on the interpretation of quantum theory, I call attention to the work by T. Haji-Hasan, A.J. Duncan, W. Perrier, H-J. Beyer, and H. Kleinpoppen (University of Stirling), who studied the two-photon decay of metastable atomic deuterium in order to test Bell's inequality. In previous, well-publicized experiments the University of Stirling physicists showed that the decay measurements were in agreement with standard quantum theory and violated Bell's inequality for a (local) hidden variable interpretation. However, because of the low detection efficiency of the photomultipliers, the objection could be raised that an unrepresentative sample of photon pairs emitted by the source was detected. In order to eliminate this objection, the authors recently inserted an achronomatic $\lambda/2$ plate in front of one of the photomultipliers. Then, as the linear polarizer (in the standard experiment) is rotated through an angle ϕ, the fast-axis of the $\lambda/2$ plate is rotated through an angle $\phi/2$, thus ensuring that the orientation of the plane of polarization of the photon entering the photomultipliers does not change as the polarization-correlation measurement is carried out. (This assurance eliminated the major possible situation of unrepresentative samples that can not be properly analyzed if detection efficiency is low.) Preliminary results indicated that the standard interpretation of quantum mechanics still holds up. Future experiments by the Stirling scientists will not only improve statistics but will also introduce a third linear polarizer in place of the $\lambda/2$ plate.

Summary

The Aberdeen meeting, by its size and liveliness, demonstrated well the continued vigorous life of British atomic and molecular physics research in academia. However, personally speaking, I was disappointed that many "hot" topics

in the area (such as clusters, atom trapping and cooling, multiphoton phenomena, Rydberg systems) were not discussed at all or only mentioned in passing. I cannot tell whether this was a consequence of some very strong prejudices on the part of the program selection committee, but I find this rather unlikely.

On the positive side I note that, as is common at British national meetings, a spirit of leisurely discussion and serenity rather than hectic rushing-around and showmanship characterized the gathering. Also, there was a good balance between theory and experiment.

One final remark is in order. It is commonly understood that results announced at meetings may be preliminary and, while serving as general information for the scholarly community, must not be quoted as if they had been published in journals. In the present case, the organizers of the conference found it necessary to state this obvious cautionary comment explicitly. Thus, though I am free to supply copies of abstracts on request for private use, readers are asked to obtain personal permission of the authors if they wish to refer to the author's work in any way.

6/24/86

THIN FILM RESEARCH AT THE UNIVERSITY OF BORDEAUX

by Paul Roman.

Solid-state physics, with an emphasis on semiconductor microelectronics research, is an area of strength and emphasis in the Physics Institute of the University of Bordeaux, France. The Laboratory for the Study of Microelectronics Materials (LEMME) is headed by Professor J. Salardenne and consists of 16 research workers (six of them permanent employees) and four technicians. The importance of the research group is underscored by its independent research laboratory status at the university and by the substantial support it receives directly from the Ministry of Research and from the National Center for Scientific Research (CNRS)--even though it is no longer an Associate Institute. In addition, private industry pays increasing interest to work in the laboratory, despite the fact that almost all research is on the basic science level.

The characteristic feature of the laboratory is its concentration on the preparation of thin films on semiconductor materials and the careful study of their properties by a variety of physical methods. Among the latter, *in situ* measurements by Rutherford backscattering is a speciality developed by researchers at LEMME.

In the following sections I review first the areas of current activity at the laboratory, then describe a typical research project (thin fluoride films on III-V semiconductors).

Research Areas

There are two main lines of research at LEMME: (1) insulating films and (2) photo-electrochemical cells.

The insulating-film research effort currently aims at developing films for the purpose of passivation in semiconductor devices. The films are grown epitaxially on III-V materials such as GaAs or InP. There are two main lines of work in this research: (1) solid solution films and (2) thermal fluorination.

The motivation for using properly chosen solid solutions for passivation is that the classical insulating materials (oxides, nitrides) lead to a non-negligible density of localized states in the forbidden band of the semiconductors near the surface. These states seem to be due to a lack of As (for GaAs) or P (for InP) and to the interruption of the periodic lattice structure at the interface of the devices. On the other hand, the lattice constant of some mixed IIA cubic fluoride alloys can be exactly matched to that of the GaAs or InP. The films at LEMME use typically solid-solution compounds of the type $Ba_{1-x}Sr_xF_2$. The reason for this choice of "alloyed" fluorides is that by varying x, one can arrange for values of the cell parameters that match those of GaAs. At present, the method used for depositing the films is vacuum sublimation, employing lab-made, sophisticated, computer-controlled equipment. But the researchers have designed a large-scale, very special-purpose vacuum chamber which is, essentially, a modified molecular beam epitaxy machine. The cost is several hundred thousand dollars, and the contractors are scheduled to deliver this one-of-a-kind piece of equipment in August. Major building reconstruction was needed for housing the new depositing-lab.

The research on thermal fluorination has two aspects: the production of insulating fluoride films and surface treatment by fluorination; the goal is to improve surface quality through the replacement of contaminating oxygen.

A few words are appropriate here on the major physical methods that are used at LEMME for the study of the thin films

they prepare. There is, of course, the classical x-ray diffraction approach, the Auger electron spectroscopy, and the more novel scanning electron microscopy work. Since these methodologies are also used for other purposes by other research groups, the LEMME researches are carried out through well-developed and efficient central-service units of the Physics Institute. However, the innovative film-study work of LEMME is done with a van der Graaf accelerator, installed two decades ago by a then vigorous nuclear physics research group of the Physics Institute. For one thing, accelerated protons are used to investigate channeling characteristics along the film crystal lattice. In this work, the technical problem is the proper collimation of the beam. The second application of the accelerator for the thin-film research is a speciality of the laboratory. It consists in the high-resolution observation of Rutherford backward scattering of alpha-particles that have been accelerated to 2 MeV energy. The observations (which require a rather long timespan) are done under high vacuum (supplied by an oil diffusion pump system). The backscattering can be observed from 160° to over 170°. These precision techniques have been used since 1985. Currently, an ambitious project is underway. Preparations are made to install an ultrahigh-vacuum system and film-deposition equipment within the vacuum cell, from which the samples prepared on the spot will simply be shifted into the high-vacuum scattering chamber. Then they may be transferred back to the ultra high-vacuum chamber for further sample-manipulation and for backscatter study. The unique research setup is expected to become fully operative by 1988.

To conclude this survey, I would like to add a few words on the second main research line of LEMME, the work with photo-electrochemical cells. These cells are prepared by depositing various liquid electrolytes on silicon. The ultimate goal is to obtain a firm scientific understanding of the production of a class of chemical gas sensors and of electrochromic displays.

Typical Research on Thin Films of Solid Solutions of Fluorides

This section highlights recent work done under the leadership of Dr. A.S. Barriére. Apart from LEMME, members of the Solid State Chemistry Laboratory of Bordeaux University are also involved.

Before attempting the actual deposition of solid solutions of fluorides onto III-V semiconductors (as summarized in the preceding section), the LEMME scientists found it necessary to make detailed physical investigations of such films when they are deposited on simpler substrates. The latter were chosen according to the purpose of the planned specific physical measurements. The reason for this "hard path" approach is that other researchers, who in the period 1982-1984 grew films on GaAs or InP substrates, obtained contradictory results and did not have a uniform composition of the film, nor could they be assured that there was no atomic disorder.

The Bordeaux researchers completed their careful preliminary studies after 3 years' work less than a year ago, and most of the results are now published in *Surface Science*, 168 (1986), 688-700.

The scientists first deposited both $(BaSr)F_2$ and $(SrCa)F_2$ solid solutions by the vacuum sublimation method (referred to above) onto a glass substrate. The layer thicknesses varied from 10 to 1,000 nm. The crystallographic state of the layers was then deduced from x-ray diffraction studies, for various substrate temperatures, during deposition. The layers (obtained, of course, on an amorphous substrate) were found to be partially crystalline for room temperature deposition, and the films showed a preferential crystallographic orientation where the <111> planes are parallel to the substrate. At higher temperatures other orientations started to appear.

In another series of only partially concluded experiments, the composition of the layers has been studied by Rutherford backward scattering (see above). In particular, the concentration profile of the elements along the depth of the layers was ascertained by a method employing rotating masks. The results revealed that the $Sr_{1-x}Ca_xF_2$ thin films are almost stoichiometric (x=0.435, the same as for the powder mix) and their composition is practically unchanged along the depth of the film. On the other hand, the composition of the $Ba_{1-x}Sr_xF_2$ samples was found to vary greatly along their depth. Eventually a constant value (x=0.930) is reached (the powder mix had x=0.825).

The energy band gap of the solid solution compounds was determined from experiments where the substrate was not glass but rather a MgF_2 single-crystal. The experiments consisted of measurement of the ultraviolet optical transmission, varying the wavelength between 100 and 310 nm. An absorption peak at 3 eV for $(SrCa)F_2$ and at 6.5 eV for $(BaSr)F_2$ was noted--and, so far, there is no theoretical interpretation for this absorption. In the high energy range, both composites showed sharp absorption peaks at 10.9 and 10.5 eV, respectively. These correspond to excitonic transitions. There is a

clear "shoulder" at 11.6 and 11.5 eV, respectively, and this indicates interband transition. Thus, for the two materials studied the energy gap is close to 11 eV.

The electrical characterization of the insulating thin-film layers was determined by creating metal-insulator-metal (MIM) structures: the films were deposited on a gold foil and then covered by a gold layer. The AC response of these MIM cells was measured with a high-precision impedance meter that was coupled to a microcomputer. The real and the imaginary parts of the admittance were determined as a function of frequency at different temperatures (some points needed 40 hours' time to be resolved sufficiently). The measurements were done between 10^{-2} and 10^{4} Hz. The major result was that the conductivity is not electronic, but almost completely ionic. The electronic conductivity was of the order 10^{-12} Scm^{-1}.

The major conclusion of the experiments was that a large band-gap, good insulating thin film of $(SrCa)F_2$ with the same lattice parameter as that of GaAs can be prepared by vacuum sublimation of solid solution powders. In this way, in the future good dielectric-semiconductor heterostructures could be fabricated with ease. On the other hand, it was shown that the hoped-for passivation of InP components by $(BaSr)F_2$ is more difficult, since the substitution factor x increased from its ideal theoretical value of 0.825 to 0.930 during evaporation. But even so, the mismatch of the $Ba_{1-x}Sr_xF_2$ layers with an InP single crystal is less than 1 percent.

Encouraged by these very careful basic preparatory studies, the LEMME researchers turned their interest a year ago toward the actual preparation and assessment of the "real thing": growing of thin layers of fluorides on GaAs and InP. The preliminary results were presented in a talk in April, at the Colloquium on Epitaxy and Passivation of III-V Compounds, at Plestin les Gréves. (A preprint, in French, is available on request.) Barriére and coworkers reported on two successful methods of preparation of dielectric thin films of fluorides used as passivating layers on III-V semiconductors. The first method is deposition under vacuum of solid solutions of $Sr_{1-x}Ca_xF_2$ and $Ba_{1-x}Sr_xF_2$, with lattice parameters close to GaAs and InP, respectively. The second method is fluorination, using a fluorine gas atmosphere, of GaAs and InP, leading to the formation of GaF_3 and InF_3 thin films. The composition of the compound layers and their concentration profile along the depth of the layers were deduced from Rutherford backward scattering and Auger electron spectroscopy measurements. The texture and crystallographic states were studied by surface electron microscopy and glancing angle x-ray diffraction methods. The results substantiated the expectations and are considered by the researchers as a firm basis for fabricating practical and eventually commercial devices.

Concluding Comments

"Provincial" science is often overlooked. In Bordeaux's LEMME, I think, we have a good example of quiet, relaxed, yet profound and conscientious research that feeds the mainstream. Apart from the scientific merits of the research, I was impressed and encouraged intellectually by the steadfast, successful leadership I saw in Bordeaux. I believe that in the future we shall hear more often of LEMME.

5/22/86

News and Notes

FOUR WESTERN EUROPEAN COUNTRIES PRESENT THEIR LATEST RESEARCH IN OPTICS AT A CONFERENCE IN THE HAGUE

Four countries (the Netherlands, the UK, West Germany, and France) banded together and organized a broad-based, high-level, mixed-constituency conference, called "Optics 86." The venue was the national congress hall in the Scheweningen section of The Hague, Holland. The unhurried, pleasant meetings took place from 21 through 24 May. Almost 300 scientists participated. There were 10 invited talks (40 minutes long) and 75 contributed papers (25 minutes). Inevitably, there was also some distraction by 16 poster papers. A small, but well organized and cleverly displayed exhibition by Western European firms in lasers, optics, and optoelectronics accompanied the conference.

Except for the invited papers, the talks were presented in two parallel sessions and the sessions grouped (not quite realistically) as follows:

- Holographic and speckle methods (two sessions)
- Imaging (two sessions)
- Image processing (two sessions)
- Optical materials

- Optical metrology
- High-speed phenomena
- Instruments and optical components
- Theoretical optics
- Vision

From my limited and prejudiced point of view, the most interesting presentations were given in the areas of nonlinear optics, optical data storage, optical computing, image processing, and optical materials. Somewhat to my surprise, topics such as micro-optics, integrated optics, laser sources and detectors for optics research, adaptive optics, etc. were not even touched upon. Nevertheless, and despite the emphasis on technical (as opposed to basic) aspects, this was a well-conducted meeting.

Many of the presentations are reviewed in technical detail in ONRL Report C-4-86. To obtain a copy, fill in the postcard on the back cover of this issue. A list of participants, and abstracts of the presentations, may also be obtained from me on request. (Please indicate which session you are interested in.)

Paul Roman
6/25/86

ADVANCED SOLID-STATE PHYSICS RESEARCH AT INNSBRUCK

The Institute for Experimental Physics, University of Innsbruck, Austria, is, next to a similar institute in Vienna, probably the best known experimental physics research center in Austria. (In most European universities there is no "Department of Physics" as such: theoretical, experimental, and applied physics departments are separated.) Due probably to the powerful leadership of its director, Professor E. Gornick, this institute appears to be well equipped with contemporary instrumentation, and one does not hear the usual Austrian cries of anguish. I recently visited two project groups (closely related and cooperating): the solid-state physics and the semiconductor physics research groups. I select two particularly interesting and, in my opinion, rather unique research areas which, apart from their basic scientific aspects, most probably have potential for serious practical applications in technology.

Semiconductor Far-Infrared Lasers

A few years ago Gornick came to the idea that in certain materials (like very pure p-Germanium) where, in strong electric fields, the scattering of optical phonons dominates other scattering mechanisms it should be possible to obtain a population inversion between the energy bands of the light and the heavy holes. With a proper arrangement, this should lead to stimulated emission and laser action. Because of lack of encouragement, the idea was put on the back burner, until about 18 months ago when it was learned that one Japanese and two Russian groups are experimenting with such systems. At this point, the Innsbruck scientists launched a massive research program under the direction of Dr. M. Helm. He told me that there may be several mechanisms responsible for causing population inversion. The most credible theory is based on the interaction of the semiconductor with optical phonons in crossed electric and magnetic fields. To test this theory, the Helm group used p-Ge samples which were centimeters long and a few millimeters thick and kept at 4.2°K in liquid helium; they applied a magnetic field of about 1 T and used electric field pulses of a few hundred volts/cm (duration: 1 μs, repetition rate: 2-10 Hz) which were applied to the sample by metallization electrodes across one of the narrow dimensions. Stimulated emission has been observed. Tuning is achieved by varying the magnetic field or the electric field; the stimulated emission can be confirmed, at this time, from about 80 to 200 μm. The efficiency is very low, 10^{-5}. In their next experiments, the scientists will use longer samples, stronger fields (better matched to the impedance), and try to construct some efficient mirror surfaces at the ends of the slab. In still another research project they will use layers of GaAs or InSb instead of p-Ge (which can be drawn in big monocrystal samples). Because of the preliminary nature of their results, the Innsbruck scientists are somewhat reluctant to be very specific; at the same time, they proudly point out that if their work proves successful it will revolutionize the production of coherent far-infrared radiation--among other advantages, power levels over 1 W can be confidently expected, they say.

Tunable, High Sensitivity Photodetectors in the Visible Range

Dr. K. Berthold, in cooperation with other scientists and undergraduate students, just concluded the first, very successful phase of a research project which can be summarized by saying that it led to the first application of metal-insulator-semiconductor (MIS) devices on holographic gratings for narrowband visible-wavelength light detection. The device is based on a controlled excitation

of surface plasmons. While surface plasmons in thin metallic films crucially influence the optical properties of such films, they cannot be excited directly by photons because their phase-velocity is too low. However, by using a periodic submicron structure over the metal surface, a controlled excitation by visible light is made possible since the periodic structure reduces the phase-velocity of the incident light. The actual system used by Berthold consisted of an Al-SiO_2-p-Si junction. The quantum efficiency was as high as 30 percent. Another experiment used an Ag-Al-SiO_2-p-Si junction. This provided a 12-nm linewidth and a remarkable signal-to-background ratio of 7:1 at the wavelength of 632.8 nm. It is very important to note that the spectral sensitivity of such photodectors can be tuned over the entire spectrum from the near-ultraviolet through the visible and up to the near-infrared; this can be achieved by a variation of tilt angle, or by a properly adjusted dielectric coating, and the use of different metals. Of course, the data of the holographic grating can also be varied to achieve different spectral widths at different wavelengths. Further research plans involve a modification where the metal film is encapsulated between two dielectric layers (with the same dielectric constant). In this case two plasmon modes may be excited, and, Berthold told me, one may then achieve a response spectral-width sensitivity as low as 1 nm.

Paul Roman
6/25/86

AERODYNAMICS RESEARCH AT THE ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

The Royal Aircraft Establishment (RAE), with locations at Farnborough and Bedford, UK, is the aircraft and aerospace research and development establishment of the UK Ministry of Defense Procurement Executive. Its role is to support the three armed services and the aerospace and aeroengine industries in the UK.

Aerodynamics research has been a major activity at RAE since 1909, and the Aerodynamics Department, which is divided between Farnborough and Bedford, has a worldwide reputation for advanced work in this field. The overall objectives of the department's research are: to advance the state of aerodynamics research, to improve aircraft/weapons performance, to reduce aerospace systems costs, and to enhance flight safety. Our visit was with the Basic Aerodynamics Division located in Farnborough, which is one of the five divisions into which the Aerodynamics Department is divided. The Basic Aerodynamics Division, presently headed by Mr. S.P. Fiddes, is concerned with obtaining a fundamental understanding of fluid mechanics phenomena which influence the aerodynamic design of aircraft and weapons, and with devising means of calculating the resultant flow-fields. The division's activities include the calculation of flow fields at transonic and supersonic speeds, the study of boundary layers, wakes, and separated flows with the emphasis on application to practical three-dimensional shapes.

Work on a fast, accurate method of solution of the Euler equations is being carried out by Dr. M.J. Hall. He uses a cell-vertex type, finite volume scheme (Hall, 1986). Cell vertex schemes have the advantage over cell-centered schemes in that mass and momentum fluxes are accurate to second order for nonsmooth, stretched grids. Hall's scheme differs from a similar method proposed by Ni (Pratt and Whitney) in that the temporal changes in the variables are conserved. This makes it possible to obtain solutions for highly stretched grids where Ni's method fails. Hall has used both Lax-Wendroff and Runge-Kutta integration methods both with and without multigrid. Another advantage of cell vertex schemes is that the tangency condition is exactly satisfied on the boundaries.

Hall demonstrated the insensitivity of his calculations to mesh spacing. His calculations for subsonic flow over an RAE 2822 and a NACA 0012 airfoil showed considerably less sensitivity to mesh spacing than the other finite difference and finite volume codes with which it was compared.

He found that accurate calculations demanded that the grid at the leading edge of the airfoil must be made extremely fine. If this is not done, spurious changes in the total pressure will result. Hall adjusted the grid size so that across any given cell the Mach number varied by less than 0.1. His calculations using a 256×32 grid required approximately 20 seconds on a CRAY-1S for a convergence on the lift coefficient to within 0.0002. He obtained results for both a RAE and NACA airfoil for several Mach numbers angles of attack.

Work on strongly separated flows is being carried out by Dr. B.R. Williams. For these calculations he uses a semidirect method (in the sense of LeBalleur) in conjunction with a panel method for

the inviscid flow and Green's lag-entrainment method for the boundary layer calculations (Williams, 1985). In comparison with measurements of subsonic flow over a NACA 4412 airfoil, Williams found his solution to represent all the essential characteristics of the flow at the trailing edge of the airfoil. The lift coefficient was predicted reasonably well, but difficulty was encountered in calculating the drag coefficient.

A study of attached flows was recently completed by Mr. M.C.P. Firman. It involved a comparison of his direct viscous-inviscid interaction methods with measurements made on a swept, highly instrumented wing designated as the RAE M2155 (Firman, 1986). Of particular interest was the accuracy of direct viscous-inviscid interaction calculations for transonic flows near separation. In his calculations, Firman used a full-potential method developed by the Aircraft Research Association (ARA) for the inviscid calculations and Green's lag-entrainment method for the boundary layer calculations. Some doubts were expressed about the accuracy of the technique, particularly as separation was closely approached. He found it impossible to pinpoint the source of the difficulties; however, the use of the potential flow method in regions where shock waves occur and the inadequacy of the coordinate transformation, particularly in the tip region, were suspected.

Unfortunately, the date of our visit coincided with the winter's heaviest snow storm and many of the members of the scientific staff were unable to make it to work. Thus, for example, we were unable to discuss the division's boundary layer work which is being done by P.D. Smith. From what we saw, work was going on in a number of areas of current interest to the aerodynamic community and there seemed to be a reasonable balance between computational and experimental efforts. Areas which seemed to be particularly well advanced were Euler solvers and the calculation of strongly separated flows.

References

Firmin, M.C.P., 'Applications of RAE Viscous Flow Methods Near Separation Boundaries for Three-Dimensional Wings in Transonic Flow," *AGARD Symposium of Applications of Computational Fluid Dynamics in Aeronautics* (Aix-en-Provence, France, April 1986, to be published).

Hall, M.G. "Cell-Vertex Multigrid Schemes for Solution of the Euler Equations," *Numerical Methods for Fluid Dynamics II*, eds. K.W. Morton and M.J. Baines (Oxford University Press: 1986), 303-345.

Williams, B.R., "The Prediction of Separated Flow Using a Viscous-Inviscid Interaction Method," *Aeronautical Journal of the Royal Aeronautical Society*, 5 (1985), 185-197.

CAPT L. Laddie Coburn, USN
Eugene F. Brown
6/11/86

THE TURING INSTITUTE

This is an update of a full article in *ESN* published early last year (*ESN* 39-2:49-52 [1985]).

Since moving to Glasgow, Scotland, in October 1984 the institute has carried out a serious buildup of its activities and it has increased its personnel to a total of 25 people, 12 of whom are research staff. There has been a modification in the affiliates scheme to allow participation in portions of the plan. For example, Industrial Affiliates may now subscribe to the library services only, if they so choose. The library is certainly one of the most complete in the world in artificial intelligence (AI) literature. There is a dial-up library data base with about 20,000 items, and it is increasing at the rate of 1000 items per month.

The software library has recently added many expert system shells, some of which were developed by the institute and some of which were purchased.

Another service which is growing rapidly is secondment from industry or universities of employees for specialized training and research in artificial intelligence and related subjects. This training and research runs over a period of 3 to 6 months, with each week divided between the two activities. Among the UK companies recently participating were British Aerospace, Rolls Royce, Imperial Chemical Industries, Racal Microelectronics, and Austin Rover. Two US companies have participated--Westinghouse and Hughes Aircraft.

Work on research contracts currently underway and the agencies for which it is being done includes:

- US Office of Naval Research, Arlington, Virginia. This work deals with the use of AI techniques in the assignment of personnel based on eligibility and policy rules. The contract began in September, 1985, and will run over a 3-year period.

- Westinghouse, US. This contract is for basic work in the interaction between two intelligent robots. The work will make use of visual perception and, possibly, voice communication. This 3-year contract began in January 1985.
- Alvey Projects. One of the two projects in which the Turing Institute is a participant is rule induction implemented into Prolog. (Other participants are ICL and Imperial College.) The second project is concerned with the processing of radiological images. (Other participants are GEC and the Medical Research Council.)
- ESPRIT. The institute participates in the use of AI in an integrated management system and in the use of expert systems in graphics.
- The Lord Corporation. This project involves use of a tactile sensor which will be incorporated as a part of the Westinghouse project.

J.F.Blackburn
6/26/86

KEY APPOINTMENT MADE IN BRITISH NATIONAL SPACE CENTER

On 2 June, Mr. Jeffrey Fellows was appointed the first Director of Projects and Technology at the British National Space Center (BNSC). He is responsible for, among other things, developing and promoting national initiatives of high technical and scientific merit either within the framework of the European Space Agency or bilaterally, and, through the BNSC Director General, advising the Defence Secretary on technology of relevance to MoD programs; he is also responsible for assuring the compatibility, efficiency, and effectiveness of the R&D activities in the various programs sponsored by BNSC.

Mr. Fellows, who is a physicist, was head of the Flight Systems Department at the Royal Aircraft Establishment (RAE), Farnborough, before joining the BNSC. He has a staff of over 200 technical and scientific staff working in the BNSC headquarters in London, at RAE Farnborough, at the Royal Signals and Radar Establishment, Defford, at the Rutherford Appleton Laboratory, Didcot, and at the Natural Environmental Research Council, Swindon.

C.J. Fox
6/30/86

STAFF CHANGES AT ONRL

With this issue we say good-bye to Dr. J. Thomas Warfield, our liaison scientist for acoustics, who has accepted a position with the Office of Naval Technology (ONT) and to Captain L. Laddie Coburn, who served here as Director of the Naval Applications Division and has been reassigned to ONT.

At this time we also welcome three new scientists to the Scientific Liaison Division and a new officer to the Military Applications Division.

Dr. Daniel J. Collins will serve as ONRL's liaison scientist for aeronautics. He is on leave during his tour here from the Naval Postgraduate School, Monterey, California, where he is a Professor of Aeronautical Engineering. Dr. William Crano is our new liaison scientist for behavioral sciences. He is on leave from the University of Texas, Austin, during his appointment here. Dr. Robert W. Vest is now serving as liaison scientist for electroceramics. Dr. Vest is on sabbatical leave from Purdue University, Lafayette, Indiana, where he is Turner Professor of Engineering in the school of Material Engineering and the School of Electrical Engineering.

Commander Dennis R. Sadowski, USN, is now responsible for Aerospace Systems Technology and its application to military aircraft and weapon systems. His most recent prior assignment was as Anti-Surface Projects Officer at the Naval Weapons Center, China Lake, California.

Commander Edmon D. Hagee, USN, is now serving as Director of the Naval Applications Division. This is in addition to his continuing responsibility as Surface Weapons Systems Technology Officer in the division.

C.J. Fox
7/9/86

CONFERENCE TO BE HELD ON POLYMERS IN A MARINE ENVIRONMENT

The Polymers Physics Group of the Institute of Physics and The Royal Society of Chemistry together with The Institute of Marine Engineers plan to hold an international conference, "Polymers in a Marine Environment," in London from 14 through 16 October 1987. An exhibition may also be held.

The conference aims to bring together practical and fundamental work relevant to marine applications of polymers. Oral or poster papers on all aspects of the field will be considered. Preliminary titles should be sent, by 31 October 1986, to: Dr. G.J. Lake, MRPPA, Brickendonbury, Hertford SG13 8NL, England. Further information can be obtained from him.

David L. Venezky
7/24/86

ONRL COSPONSORED CONFERENCES

ONR, London, can nominate two registration-free participants in the conferences it supports. Readers who are interested in attending a conference should write to the Scientific Director, ONRL, Box 39, FPO New York 09510.

Aerodynamics at Low Reynolds Numbers, London, England, 15-17 October.

Domain Decomposition Methods For Partial Differential Equations, Rocquencourt, France, 5-7 January 1987.

* * *

JUNE MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR, London, Military Applications Division during June. The *MAS Bulletin* is an account of accomplishments in European naval research, development, test, and evaluation. Its distribution is limited to offices with the US Department of Defense. DoD organizations should request copies of the *Bulletins*, by number, from ONR, London.

MASB Number	Title
38-86	Arctic Weather--Undetected Storms
39-86	Avionics Technology for the UK EAP Flight Demonstrator
41-86	ERS-1 SAR Performance Verification

ONRL REPORTS

To request reports, indicate the report number on the self-addressed mailer and return it to ONR, London.

R-3-86 *Welding Science and Technology in Europe: A Survey and Assessment*, by Kenneth D. Challenger. Welding research is organized and coordinated differently within each country, but the International Institute of Welding serves to coordinate the results on an international scale. The UK, West Germany, and Scandinavia are leading the technological progress in Western Europe, but Eastern Europe places more emphasis on welding research than does the West. In all of Europe the research tends to be applied rather than basic. This report includes a list of key people.

R-4-86 *Materials Science in Europe: A Summary Report*, by Kenneth D. Challenger. This report covers highlights of European research in welding science and technology, composite materials, fracture mechanics, ceramics, and other specialized topics.

C-5-86 *Optics '86: Four Western European Countries Review Recent Achievements*, by Paul Roman. The conference in The Hague covered a very broad field of topics, including optoelectronics. This review highlights presentations on nonlinear optics, optical data storage and optical computing, image processing, and novel optical materials.

CHANGE REQUEST
NAVEUR-ONR-5605/1 (Rev. 3-85)

FOR YOUR CONVENIENCE . . .

Government regulations require up-to-date distribution lists for all periodicals. This form is provided for your convenience to indicate changes or corrections. If a change in our mailing lists should be made, or if you want any of the ONRL publications abstracted in this issue and listed below, please check the appropriate boxes. Fold on dotted lines, being sure our address is on the outside, tape or staple the lower edge together, and mail.

1. ☐ CHANGE OR CORRECT MY ADDRESS EFFECTIVE IMMEDIATELY OR (date)
2. ☐ DELETE MY NAME FROM DISTRIBUTION LIST
3. ☐ PLEASE SEND ME THE FOLLOWING ONRL PUBLICATIONS

Corrected or New Address

☐ R-3-86 ☐

☐ R-4-86 ☐

☐ C-5-86 ☐

☐ ☐

☐ ☐

☐ ☐

Fold Here

Fold Here

FROM:

_____

_____

_____

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 12503 WASHINGTON DC

POSTAGE WILL BE PAID BY DEPARTMENT OF THE NAVY

Commanding Officer
Office of Naval Research, Branch Office
Box 39
FPO New York 09510-0700